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NATIONAL BUREAU OF STANDARDS REPORT

8138

CAPACITY TESTS OF FOUR REMOTE AIR-COOLED
REFRIGERANT CONDENSERS

Manufactured by
Kramer Trenton Company
Trenton 5, N.J.

by

C. W. Phillips

to
Mechanical Engineering Division
Quartermaster Research and Engineering Command
Natick Laboratories, U. S. Army
Natick, Mass.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
1003-20-10435	December 5, 1963	8138

CAPACITY TESTS OF FOUR REMOTE AIR-COOLED
REFRIGERANT CONDENSERS

Manufactured by
Kramer Trenton Company
Trenton 5, N.J.

by

C. W. Phillips
Mechanical Systems Section
Building Research Division

to

Mechanical Engineering Division
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U. S. DEPARTMENT OF COMMERCE
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CAPACITY TESTS OF FOUR REMOTE AIR-COOLED
REFRIGERANT CONDENSERS

MANUFACTURED BY
KRAMER TRENTON COMPANY
TRENTON, NEW JERSEY

by
C. W. Phillips

1.0 Introduction

This report presents results of capacity tests of four remote air-cooled refrigerant condensers, of three sizes and three classes listed in "Purchase Description, Condensers, Air-Cooled, for Use with Dichlorodifluoromethane (F-12)", dated March 22, 1957 All four were manufactured by Kramer Trenton Company, Trenton, New Jersey.

The four condensers were:

Specimen No. 1 Size A Class 1
Copper Tubes, Aluminum Fins
NBS Test No. 134-57

Specimen No. 2 Size B Class 3
Aluminum Tubes, Aluminum Fins
NBS Test No. 145-58

Specimen No. 3 Size B Class 2
Copper Tubes, Copper Fins
NBS Test No. 146-58

Specimen No. 4 Size C Class 1
Copper Tubes, Aluminum Fins
NBS Test No. 150-58

Specimen No. 1 was procured under contract No. DA 19-129-QM-827, and the other three were procured under contract No. DA 19-129-QM-1013.

1.1 Background

This report is the final report of several presenting test data on the performance of a number of air-cooled refrigerant condensers. The study was resumed in July 1959 following a period of inactivity for fiscal reasons. Results of previous tests in the series have been presented in NBS Reports 6378, 6401, 6420, 6670, and 7760. Apparatus

designed and constructed specifically for this work was originally patterned after a then proposed ASRE Standard, PS-2.4. During the time the test project was inactive, the proposed ASRE Standard PS-2.4 was modified and adopted as ASHRAE Standard 20-60, "Methods of Testing for Rating Remote Mechanical-Draft Air-Cooled and Evaporative Condensers". It should be noted that ASRE (American Society of Refrigerating Engineers) and ASHAE (American Society of Heating and Air-Conditioning Engineers) merged in 1959 to form ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). The primary change between ASRE PS-2.4 and ASHRAE Standard 20-60 affecting this test series was the substitution of a low side refrigerant calorimeter for the air-side psychrometric measurement of heat rejection. In reactivating the project, the air-side psychrometric measurement was retained, and the original test system evaporator was modified to function as a low-side refrigerant calorimeter. For some tests a separate low-side refrigerant calorimeter was used. The use of a turbine-type electronic flowmeter for determination of liquid refrigerant flow rate was retained as the primary flow rate method.

Neither ASRE PS-2.4 or ASHRAE Standard 20-60 established requirements for minimum or maximum subcooling of the liquid refrigerant leaving the condenser. Failure to control the degree of subcooling to as low a positive value as possible, and certainly failure to condense completely, will result in unsuitable comparisons of different test condensers. QMR&E Purchase Description, "Condensers, Air-Cooled for Use with Dichlorodifluoromethane (F-12), dated March 22, 1957 does not specify either minimum or maximum degree of subcooling. Military Specification MIL-C-23122, "Condensers, Air-Cooled, Refrigerant-12", dated December 27, 1961 specifies a minimum subcooling of three degrees F, and no maximum. All tests described in this and previous reports in this study were made with condensation of all of the refrigerant (indicated by a clear sight glass at the condenser outlet) and with subcooling less than five degrees F in most cases and less than 10.5 degrees F in all cases.

ASRE PS-2.4 included Standard Rating Conditions; ASHRAE Standard 20-60 does not. QMR&E Purchase Description, "Condensers, Air-Cooled for Use with Dichlorodifluoromethane (F-12)" dated March 22, 1957, set forth the following capacity requirements, at an entering saturation refrigerant temperature of 135°F and 25°F temperature difference between the entering air (110°F) and entering saturation refrigerant temperature (135°F) for the four sizes of condensers:

Size A	22,300	Btu/hr (Min.)
Size B	35,600	Btu/hr (Min.)
Size C	46,000	Btu/hr (Min.)
Size D	57,000	Btu/hr (Min.)

Capacities have been determined at these conditions and also at the following conditions as suggested in ASRE PS-2.4:

	High Rate	Low Rate
Dry bulb temperature of air entering unit	95°F	95°F
Wet bulb temperature of air entering unit	75°F ± 5°F	75°F ± 5°F
Dry bulb temperature of ambient air	95°F	95°F
Saturation temperature of dry refrigerant vapor entering condenser	130°F	105°F
Actual temperature of dry refrigerant vapor entering condenser	195°F ± 10°F	170°F ± 10°F

Other relevant document changes occurring since the original implementation of these tests include Military Specification MIL-C-23122, "Military Specifications for Condensers, Air Cooled, Refrigerant-12", adopted December 27, 1961, and proposed Military Standard "Condensers, Air Cooled, Refrigerant," (FSC 4130).

2.0 Test Apparatus and Procedures

The test apparatus and procedures used were similar to those used for tests previously reported in NBS Reports 6378, 6401, 6420, 6670, and 7760, except as modified to conform generally to ASHRAE Standard 20-60, "Standard Methods of Testing for Rating Remote Mechanical Draft Air Cooled or Evaporative Condensers."

Tests were run in general conformance with requirements of ASHRAE Standard 20-60. A few points of non-conformance are discussed.

1. The requirement in Section 4-2 of ±0.1°F accuracy of absolute temperature measurements is unrealistic for normal laboratory-quality measuring systems. ±0.2°F is more realistic, and test results reported were based on measurements approaching this degree of accuracy.

2. ASHRAE Standard 20-60 requires two simultaneous determinations of refrigerant flow rate as the means for determining performance. Tests reported here compare a psychrometric "air-side" measurement with a simultaneous refrigerant flow rate measurement by an electronic turbine-type flowmeter. On each run at least these two independent determinations of capacity were made. On some of the runs, the evaporator in the test circuit was adapted and instrumented to serve as a low-side refrigerant calorimeter to provide

a third measurement, in direct comparison with the turbine-type liquid refrigerant flowmeter determination made in all runs. On some runs a separate secondary refrigerant calorimeter was used to provide the comparison with the flowmeter.

3. ASHRAE Standard 20-60 does not establish requirements for maximum or minimum subcooling of the liquid refrigerant leaving the test condenser. In fact, only by inference does it require that all refrigerant vapor entering the condenser must be condensed. Tests reported were all run with minimum subcooling. The desired subcooling was controlled by means of an adjustable flow valve at the receiver inlet.

4. A printing error in ASHRAE Standard 20-60 in the formula for determination of q_c, condensing heat rejection, resulted in a lack of guidance for this somewhat arbitrary calculation. Based on ASRE PS-2.4, it was assumed that q_c should be based on the enthalpy difference between the entering refrigerant vapor (at P_{2c}, t_{2c}) and refrigerant liquid at saturation temperature corresponding to the inlet pressure (P_{2c}). Note further discussion under "Data and Results".

The three independent measuring systems can be described briefly:

1. Air-side or Psychrometric. The test condenser was mounted in one end of an insulated air duct apparatus installed in a test room with ambient temperature, and humidity controlled at the specified condenser entering air conditions. The air was drawn through the condenser by a selected fan discharging at atmospheric pressure in a chamber large enough to simulate free discharge. The air was drawn out of this chamber through a long radius nozzle by means of an auxiliary blower which discharged into the surrounding room temperature and humidity controlling apparatus. Condenser heat rejection capacity was determined by measuring air quantity and enthalpy change and correcting for fan motor energy input.

2. Liquid Refrigerant Flowmeter. The subcooled condensed liquid refrigerant was metered by means of a totalizing (integrating) electronic turbine-type flowmeter, and heat rejection capacities were determined from refrigerant mass flow and enthalpy change.

3. Low-Side Calorimeter. Liquid refrigerant flow was determined by means of measurement of the enthalpy change in the refrigerant and the energy (heat) required to evaporate the refrigerant in an insulated, metered, electrically heated evaporator using one or the other of two low-side calorimeters. One was the original

tube-type evaporator equipped with immersion electric heaters, modified to operate as a dry system primary calorimeter by installing electric energy meters, thermocouples, and better insulation. Although this calorimeter was satisfactory for the larger size condensers producing liquid refrigerant flow rates greater than about eight pounds per minute, its over-all accuracy was not considered suitable for useful comparison at lower flow rates, particularly below four pounds per minute. The probable reason for this was failure to accurately determine calorimeter heat leakage at the lower evaporator temperatures occurring at the lower flow rates. A secondary refrigerant calorimeter constructed for a previous study was used for the one Size A condenser (Specimen No. 1) included in this report.

Figures 1 through 8 show certain features of the test apparatus and instrumentation.

Figure 1. Schematic drawing of complete measuring apparatus.

Figure 2. Inclined gauges and manometers for air pressure measurements, totalizing counter for refrigerant liquid flowmeter, barometer, hot and cold temperature reference baths. Switch box (lower left) controlled position of auxiliary blower inlet damper.

Figure 3. Wet- and dry-bulb thermocouple grid at test condenser air inlet.

Figure 4. Auxiliary blower (left) and inlet damper control motor. Blower is at exit end of air duct apparatus.

Figure 5. Condensed refrigerant liquid line leaving test condenser (right). Pressure tap (right), sight glass (center), and thermocouple well (left) are part of measuring system for determining temperature and degree of subcooling of leaving refrigerant liquid. A mixer (Fig. 12) was installed between the condenser and sight glass for most runs.

Figure 6. Test system refrigerant pressure gauges and precision galvanometer type potentiometer.

Figure 7. Instruments for measurement of electric energy, current and voltage, and relative humidity.

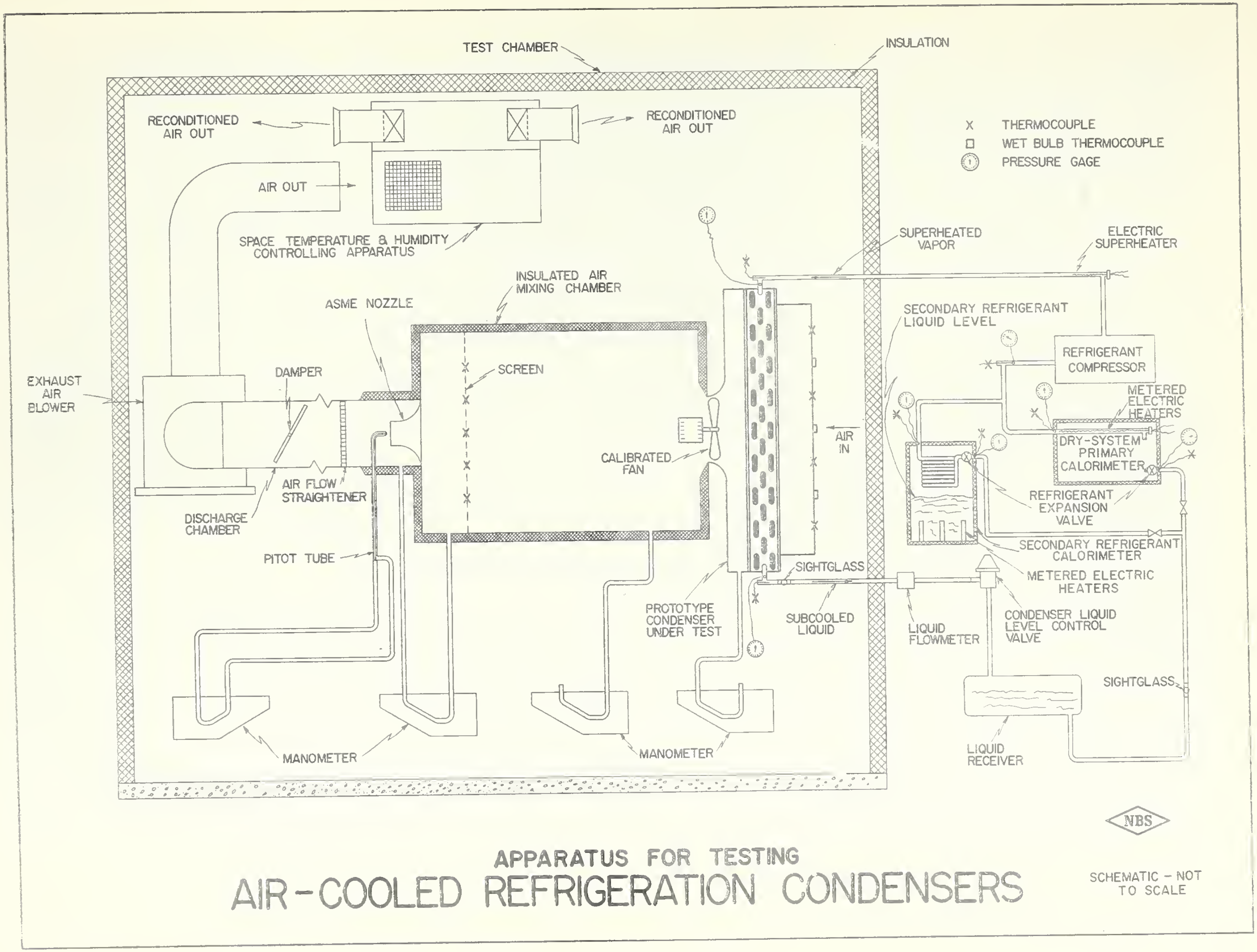

TEST CHAMBER
INSULATION
RECONDITIONED AIR OUT
RECONDITIONED AIR OUT
X THERMOCOUPLE
WET BULB THERMOCOUPLE
PRESSURE GAGE
AIR OUT
SPACE TEMPERATURE & HUMIDITY CONTROLLING APPARATUS
SUPERHEATED VAPOR
ELECTRIC SUPERHEATER
INSULATED AIR MIXING CHAMBER
ASME NOZZLE
SECONDARY REFRIGERANT LIQUID LEVEL
REFRIGERANT COMPRESSOR
EXHAUST AIR BLOWER
DAMPER
SCREEN
METERED ELECTRIC HEATERS
DRY-SYSTEM PRIMARY CALORIMETER
AIR IN
CALIBRATED FAN
AIR FLOW STRAIGHTENER
REFRIGERANT EXPANSION VALVE
DISCHARGE CHAMBER
SECONDARY REFRIGERANT CALORIMETER
PITOT TUBE
SIGHTGLASS
METERED ELECTRIC HEATERS
PROTOTYPE CONDENSER UNDER TEST
SUBCOOLED LIQUID
LIQUID FLOWMETER
CONDENSER LIQUID LEVEL CONTROL VALVE
SIGHTGLASS
MANOMETER
MANOMETER
LIQUID RECEIVER
NBS
APPARATUS FOR TESTING
AIR-COOLED REFRIGERATION CONDENSERS
SCHEMATIC - NOT TO SCALE

Fig. 1

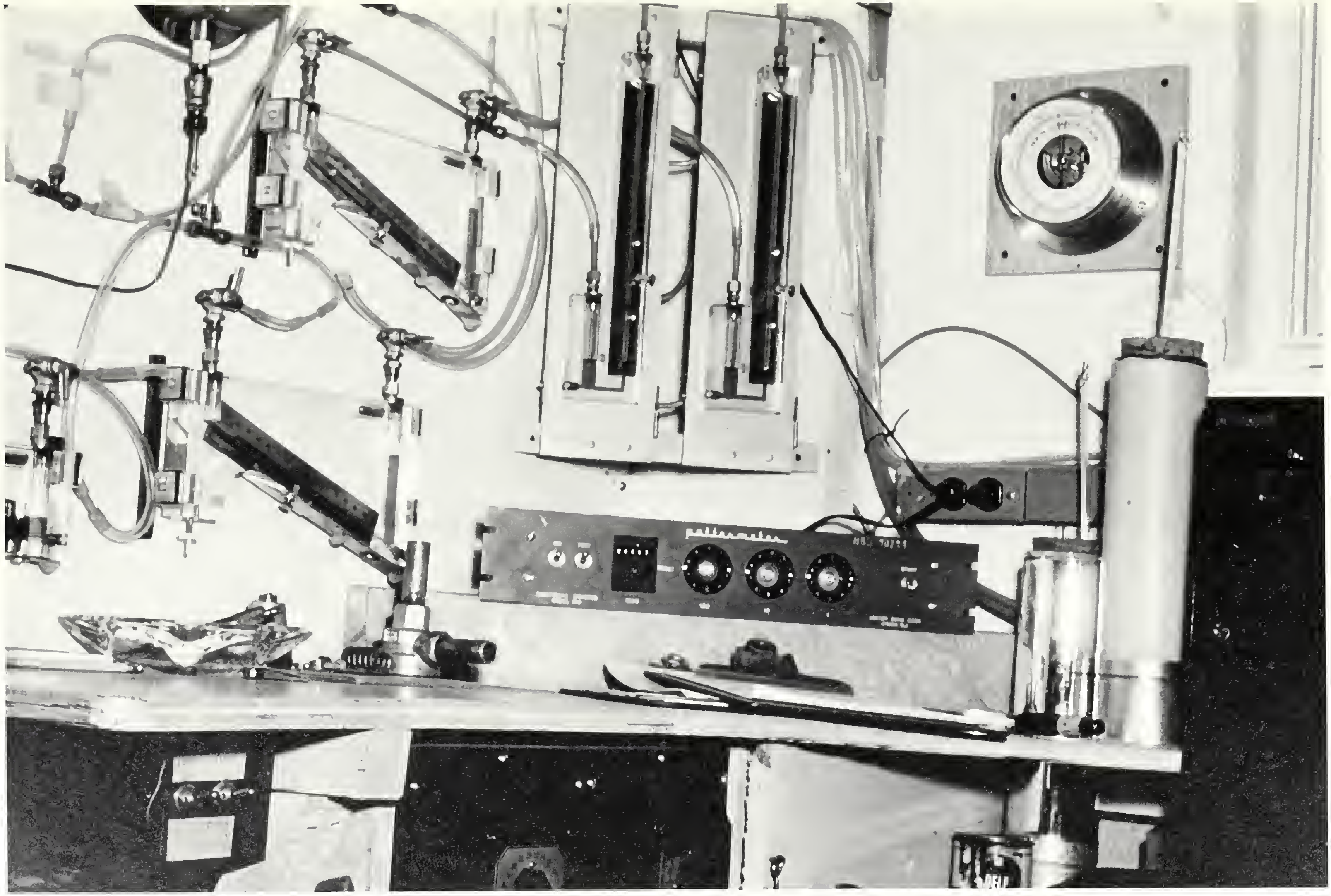


Fig. 2

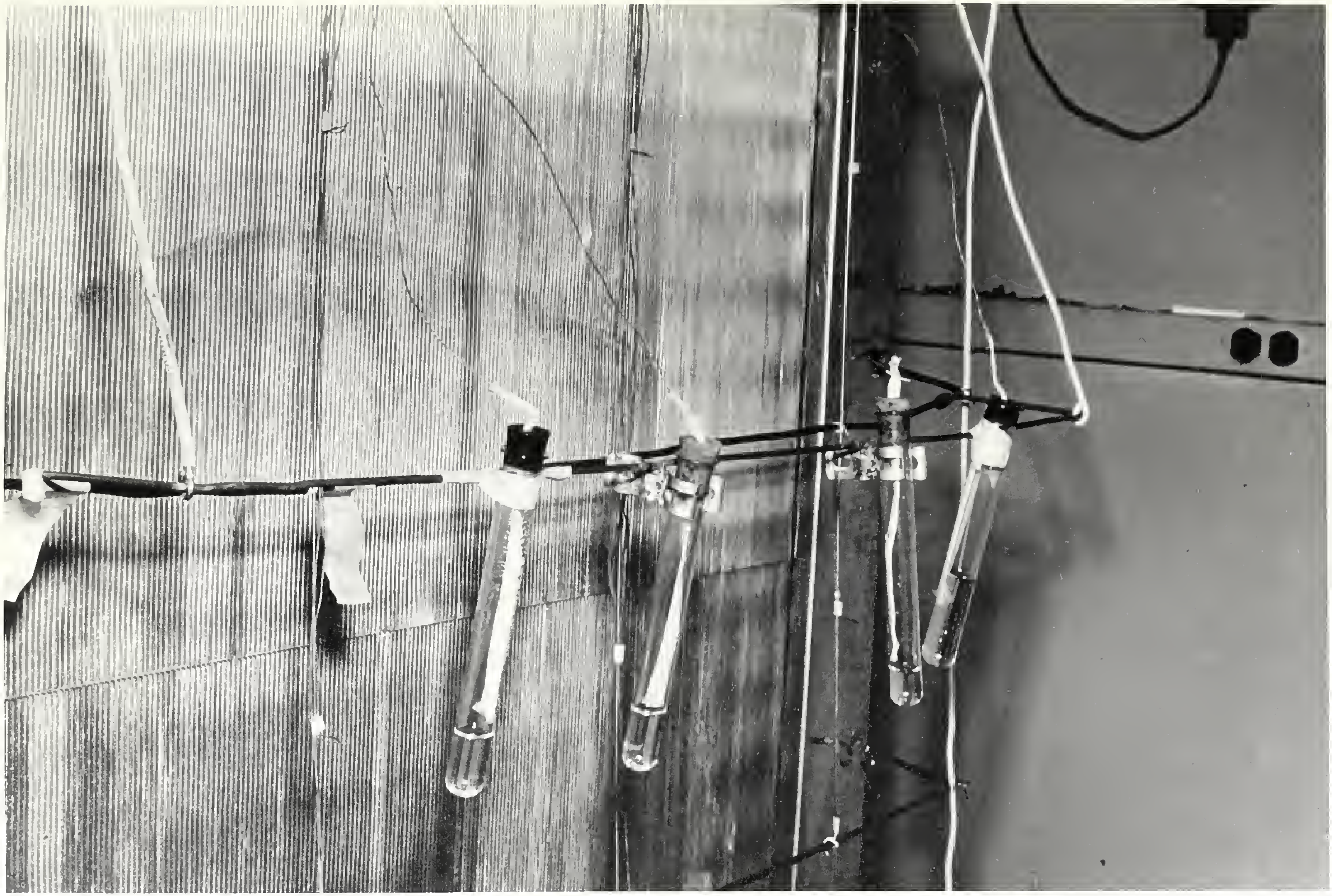


Fig. 3

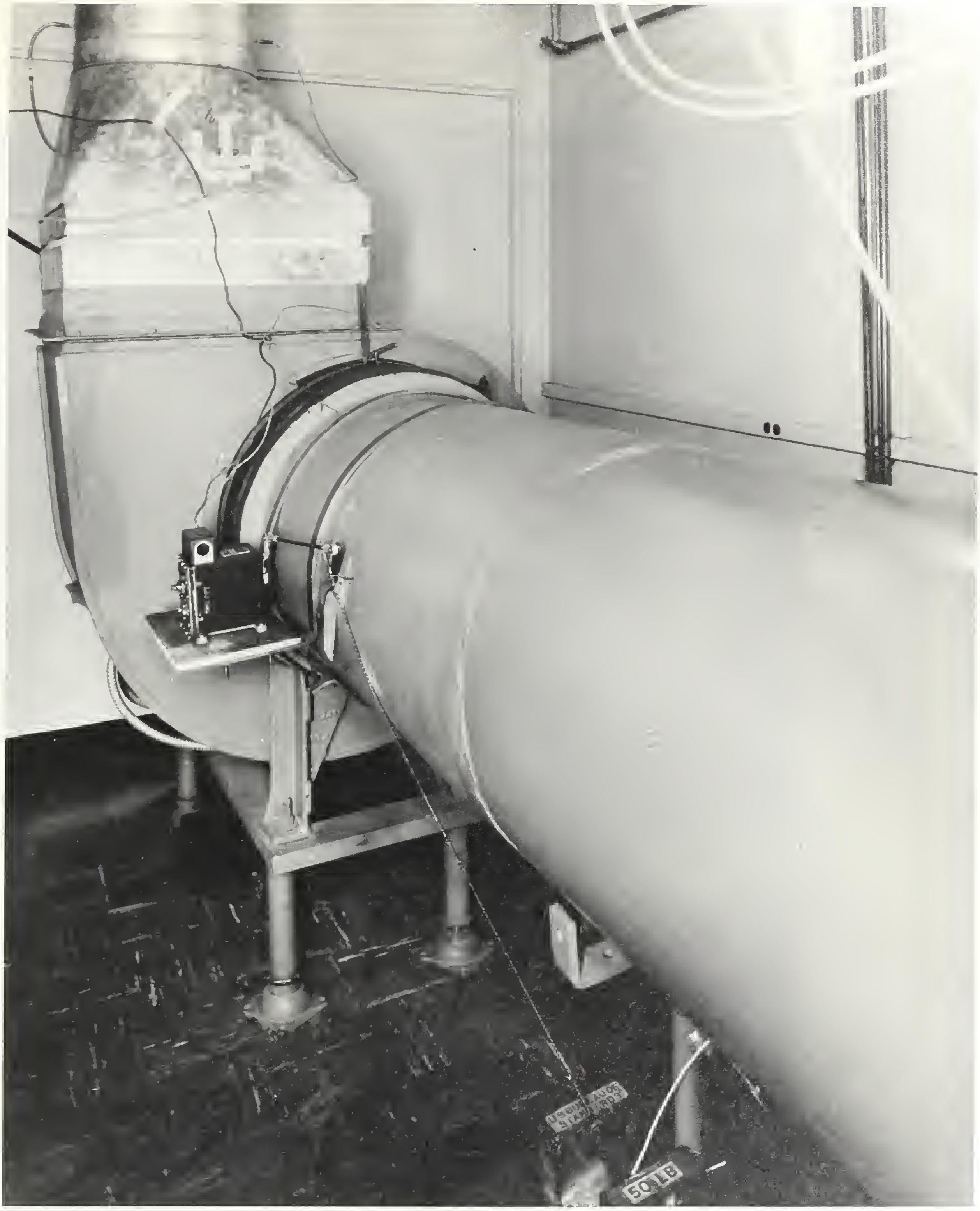


Fig. 4

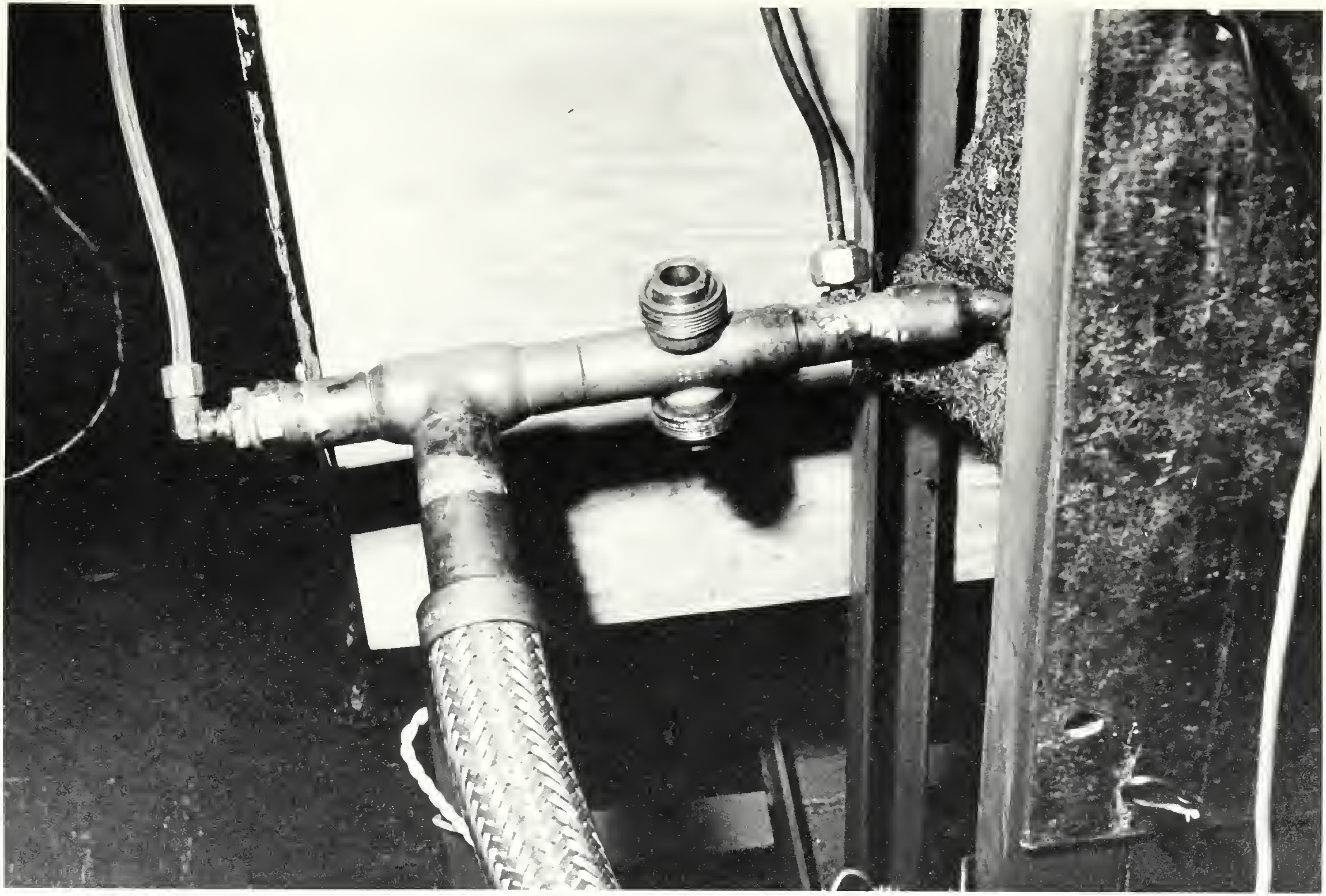


Fig. 5

Fig. 6

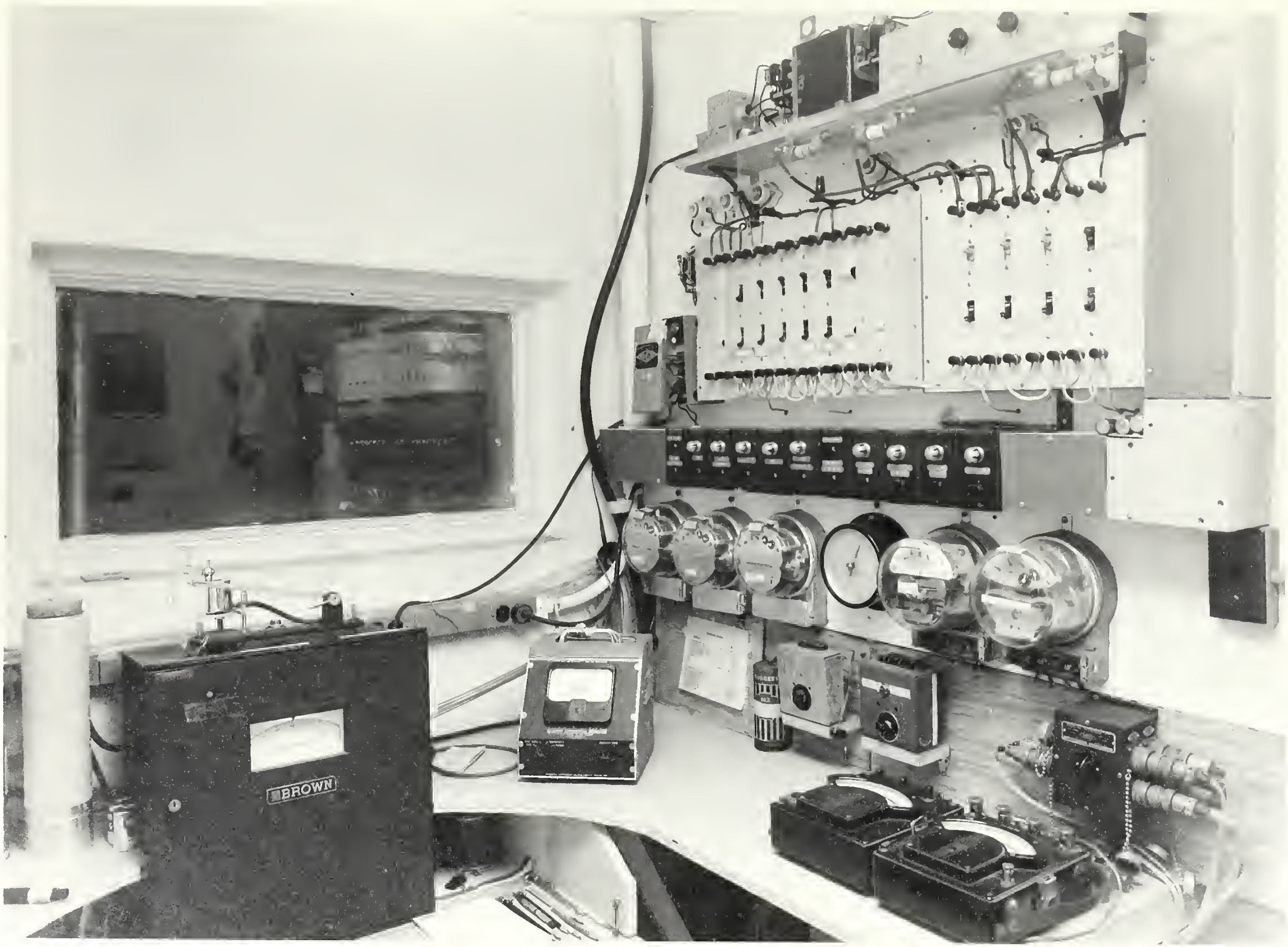


Fig. 7

Figure 8. Components of condenser test circuit including compressor, vertical liquid receiver, primary dry system calorimeter evaporator (in plywood enclosure, top), and various accessories for controlling and measuring refrigerant temperatures, pressures and flow. Two pressure gauges (center) indicate pressure drop across liquid line flowmeter(s) directly above gauges. The vertical liquid receiver was located near an outside door, and during cold weather was influenced by frequent and excessive changes in ambient temperatures not experienced during earlier tests. These temperature changes interfered with control of subcooling. A water coil was formed around the receiver, with water flow controlled by receiver refrigerant pressure and the entire assembly insulated as shown, eliminating the effect of ambient temperature changes. Water-cooling the receiver also facilitated pump down of the refrigerant when changing test condensers.

Figure 9. Secondary refrigerant calorimeter.

Additional details concerning apparatus will be found under "Data and Results".

3.0 Data and Results

Each condenser was studied at three different sets of standard conditions as previously described. Each test required control of refrigerant inlet temperature and pressure, air inlet temperature and pressure, air outlet pressure and refrigerant subcooling. Although each condenser was supplied with its own fan and fan motor, tests were made using a selected military standard fan and fan motor conforming to the fan air delivery vs. static pressure requirements of the purchase description. Figure 10 shows the three fan types and two motors used for the series.

Figure 11 shows the typical construction of the tube and embossed plate fin assembly used in all of the condensers covered in this report. Note the 5/32-in. open slots between alternate pairs of tube openings. In manufacture, the end of certain of the return bends of the nominal 3/8-in. o.d. serpentine tube coils used for all condensers covered by this report were flattened, the coils then inserted in the fin assembly and then expanded hydraulically. This operation reopened the flattened return bends and also expanded the tubes into the fin collars extruded from the fins. Final expanded diameter of the tubes was somewhat larger than 3/8 in., approximately 0.39 in. The determinations of primary, secondary and total surface areas were based on the following conditions:

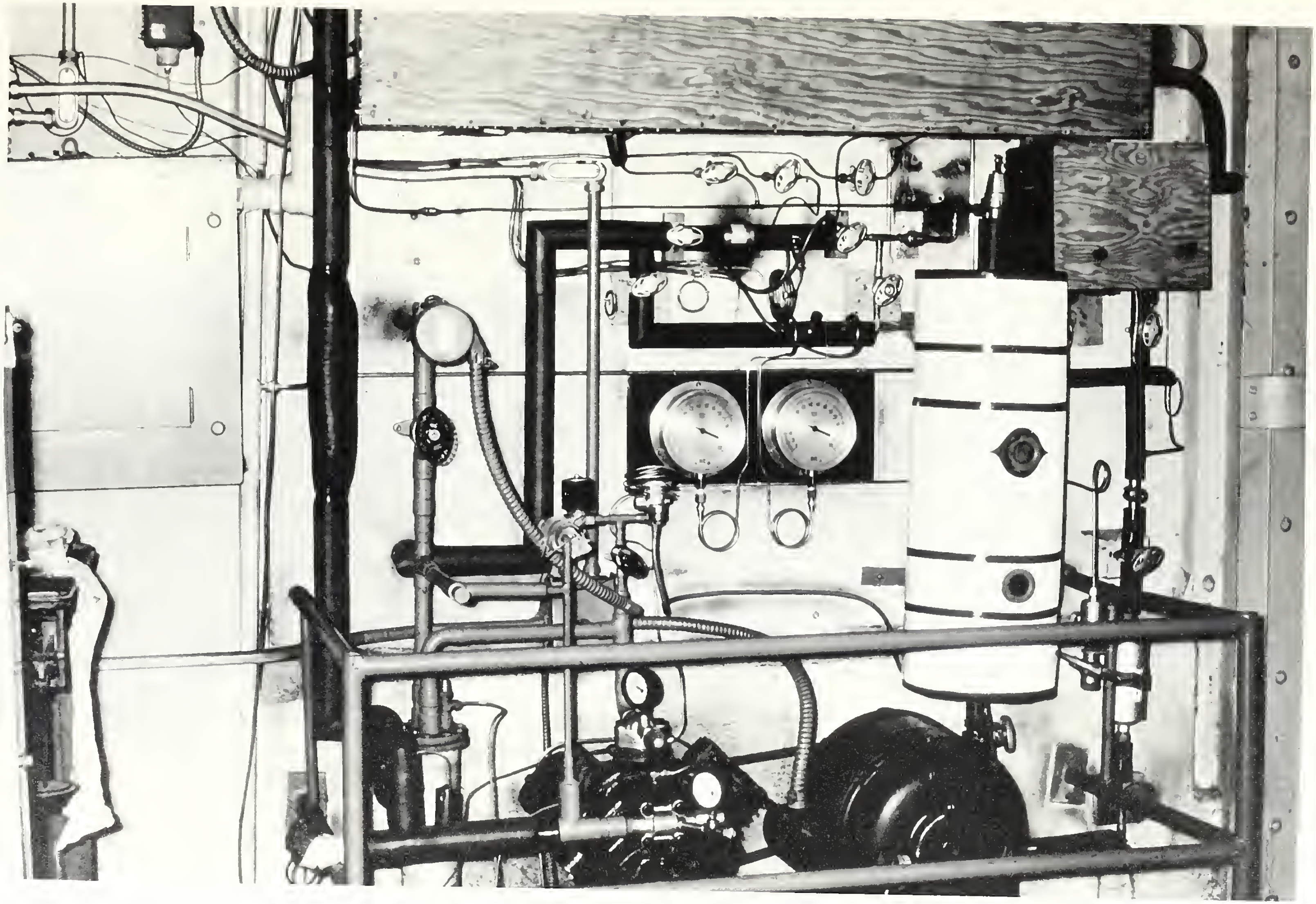


Fig. 8

Fig. 9

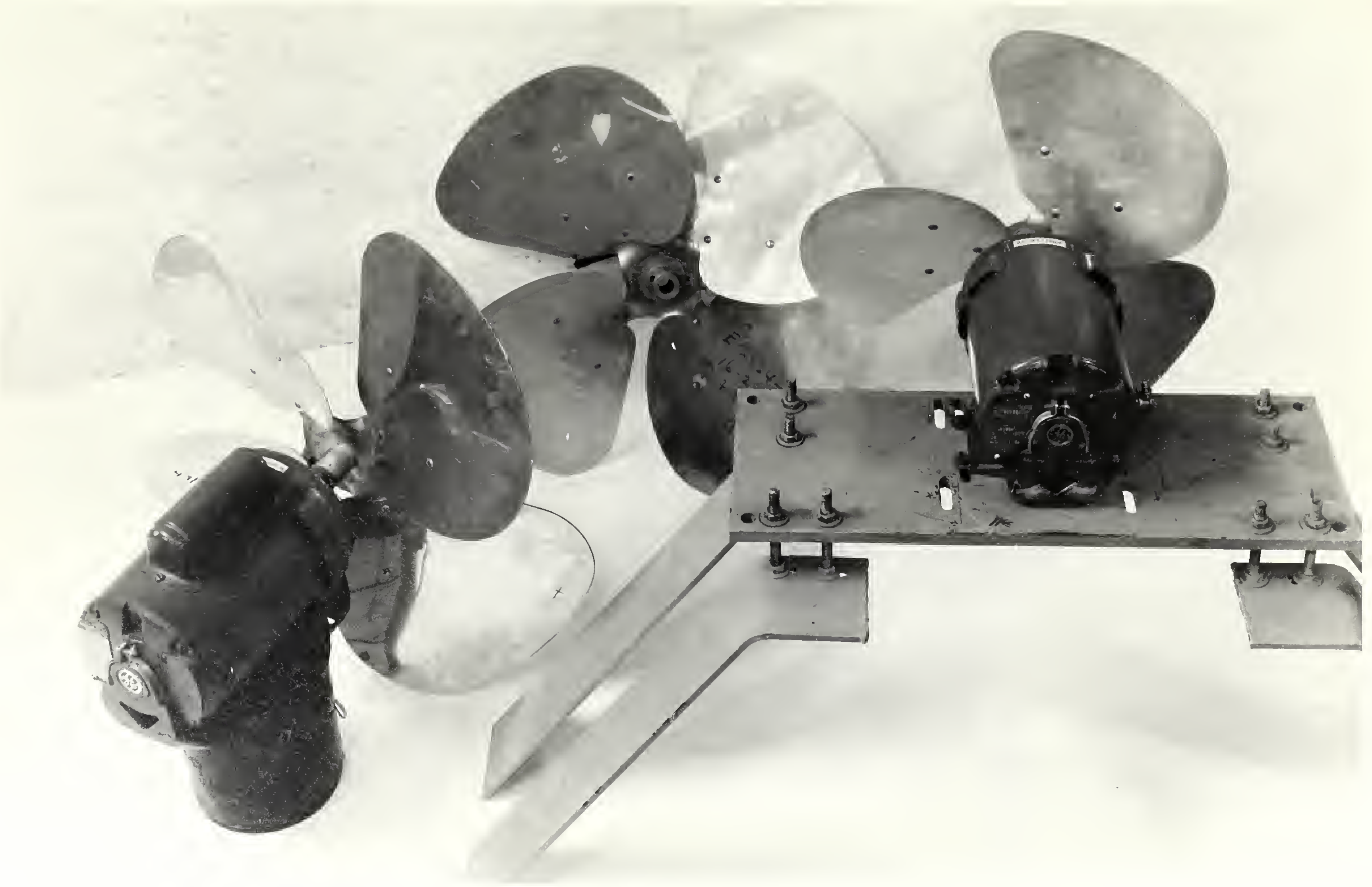
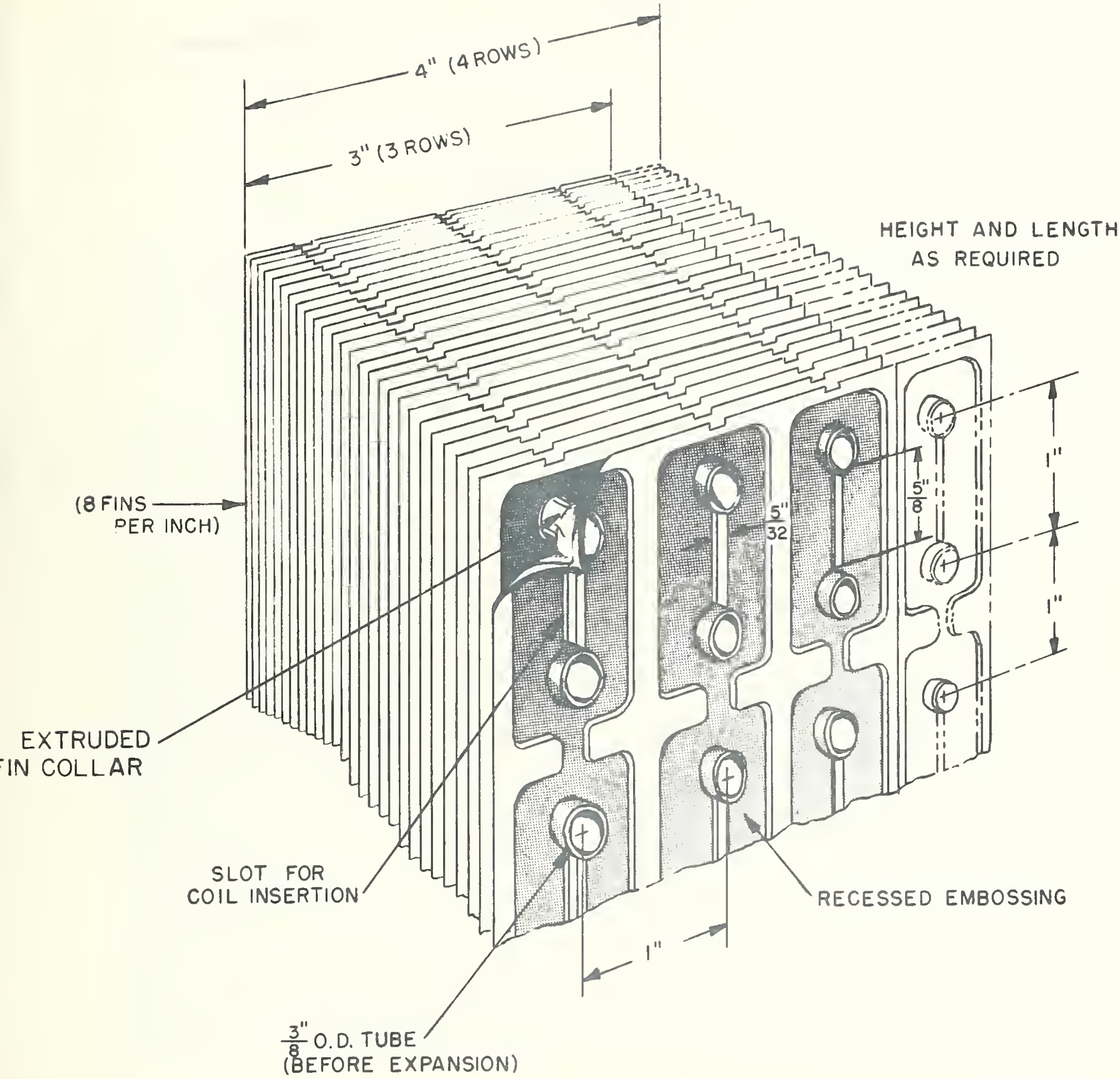


Fig. 10



TYPICAL FIN AND TUBE ASSEMBLY

Fig. 11

1. Primary area = Number of tubes x length x π x diameter minus area covered by fins based on fin thickness. Fin collars were ignored. Tube outside diameter was taken arbitrarily as 0.375 in.

2. Area of open slots and tube openings was deducted from total fin area.

3. End sheets and tube area through and beyond end sheets and exposed fin edges were not included.

In an earlier report (NBS 6670) of tests of two condensers also manufactured by Kramer Trenton Company area was determined on slightly different basis in that (1) primary area = total tube area in the finned width, and (2) secondary area was not corrected for insertion slot area.

Figure 12 shows a mixing device which was used in the condenser outlet line for all tests except two covered in this report. One of these two tests was included for comparison; the other was conducted prior to construction of the mixing device.

Figure 13 shows, schematically, the features of the mixer, which consisted of an insulated cylinder of 5-in. diameter, about 6 in. high, with the inlet about 1 1/2 in. from the top and the outlet at the bottom. During initial tests of one of the condensers in this report, a clear sight glass in the refrigerant liquid line leaving the condenser was not obtained with pressure-temperature relationships observed at the sight glass of less than 4.0 degrees of indicated subcooling. Temperature measurements of the last return bend in each row indicated the possibility that one or more rows were passing some uncondensed vapor while the other rows were passing subcooled liquid. After the mixer was added, satisfactory agreement of subcooling was obtained between the sight glass and the pressure-temperature relationship of the refrigerant at the sight glass. Because the mixer was well insulated, it functioned adiabatically and did not increase the total heat exchange of the condenser. A comparison test with and without the mixer in the circuit indicated agreement within 0.9 percent, a difference smaller than the ability of the apparatus to provide a precise comparison. These comparative observations are included in the discussion of test results obtained with Specimen No. 2.

Figure 14 is a pressure-enthalpy diagram for dichlorodifluoromethane (Refrigerant 12) on which the three sets of rating conditions used for the tests in this report are shown. Symbols used in the Tables of Test Results are identified on this diagram.

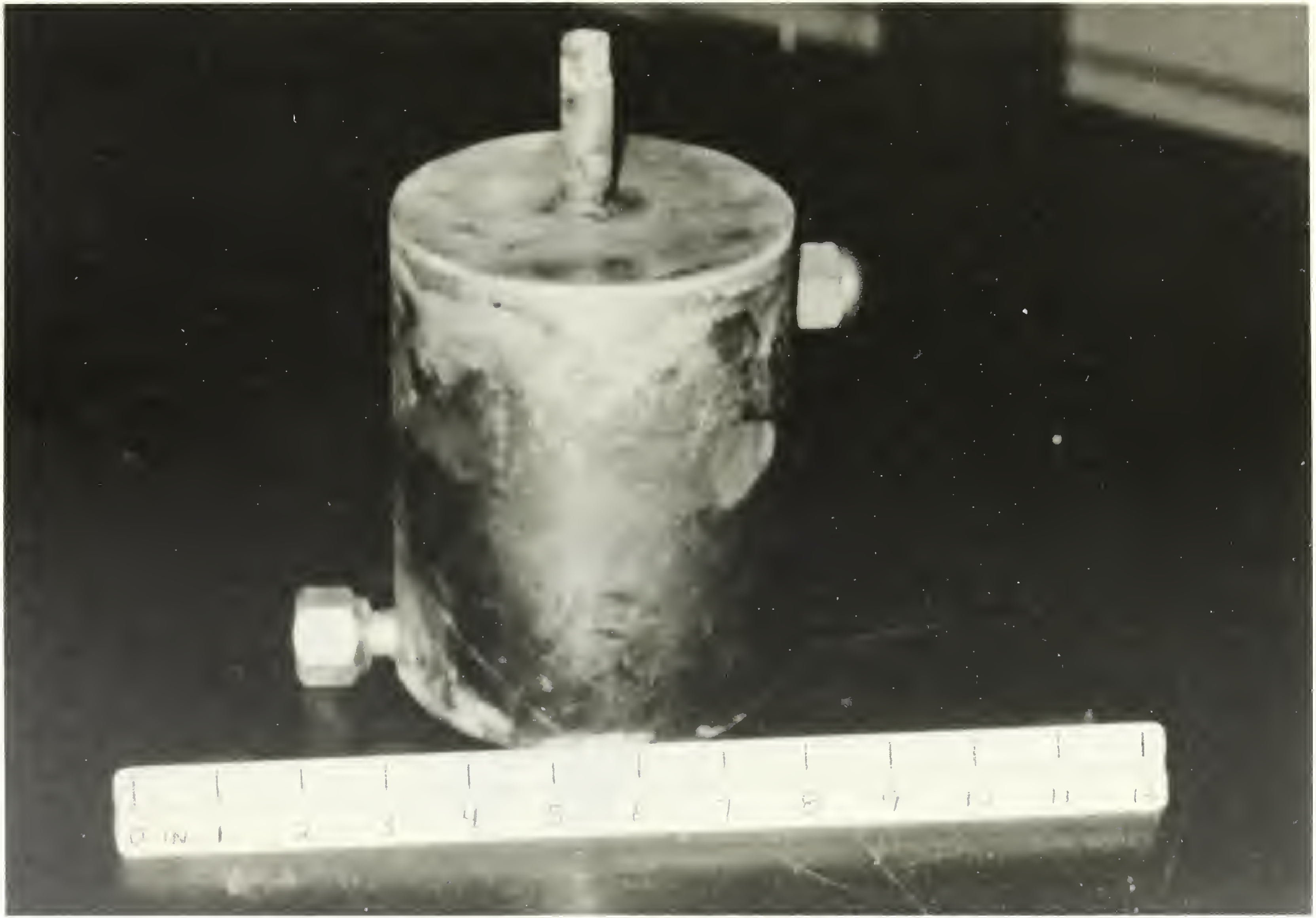
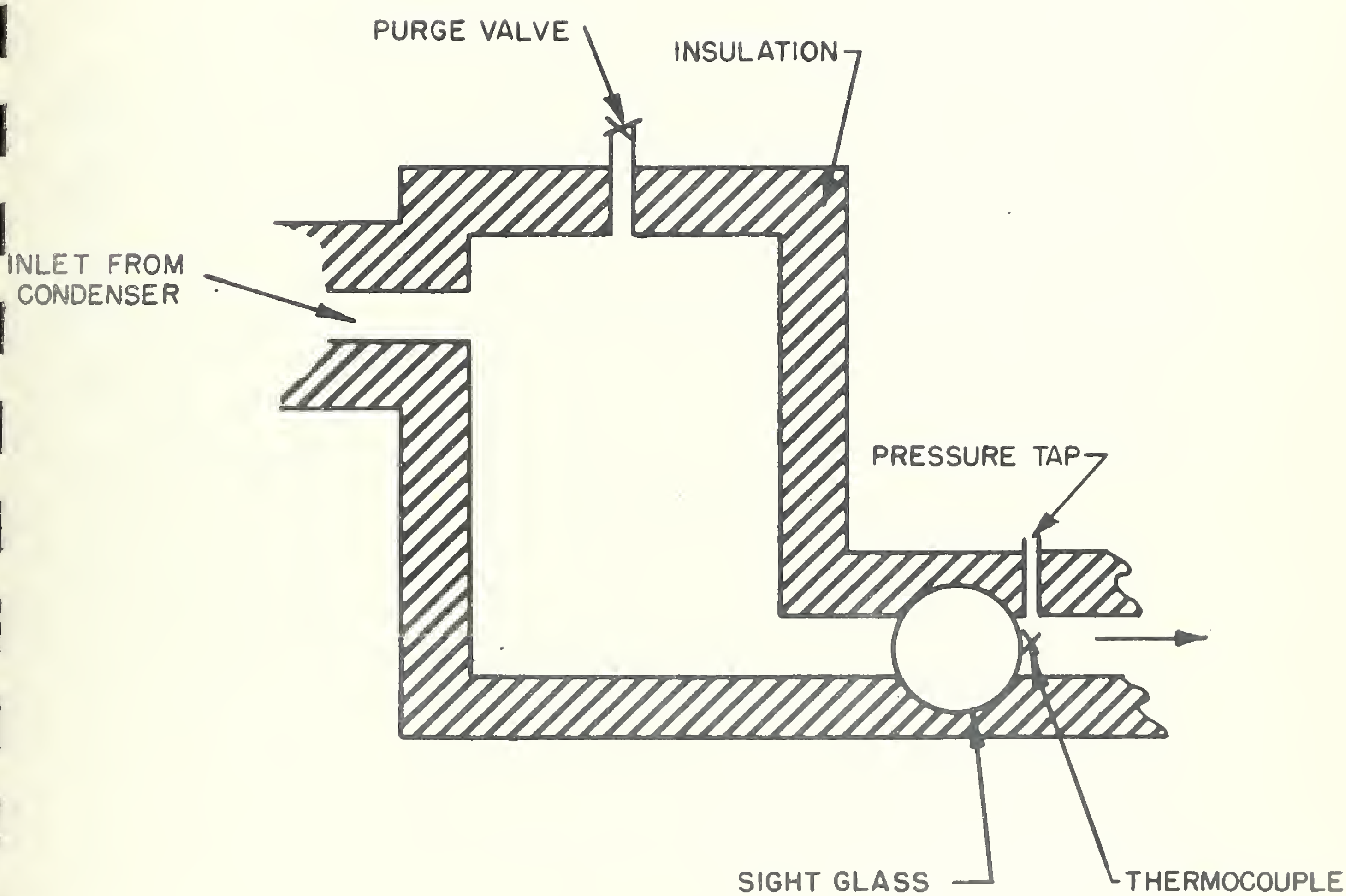


Fig. 12

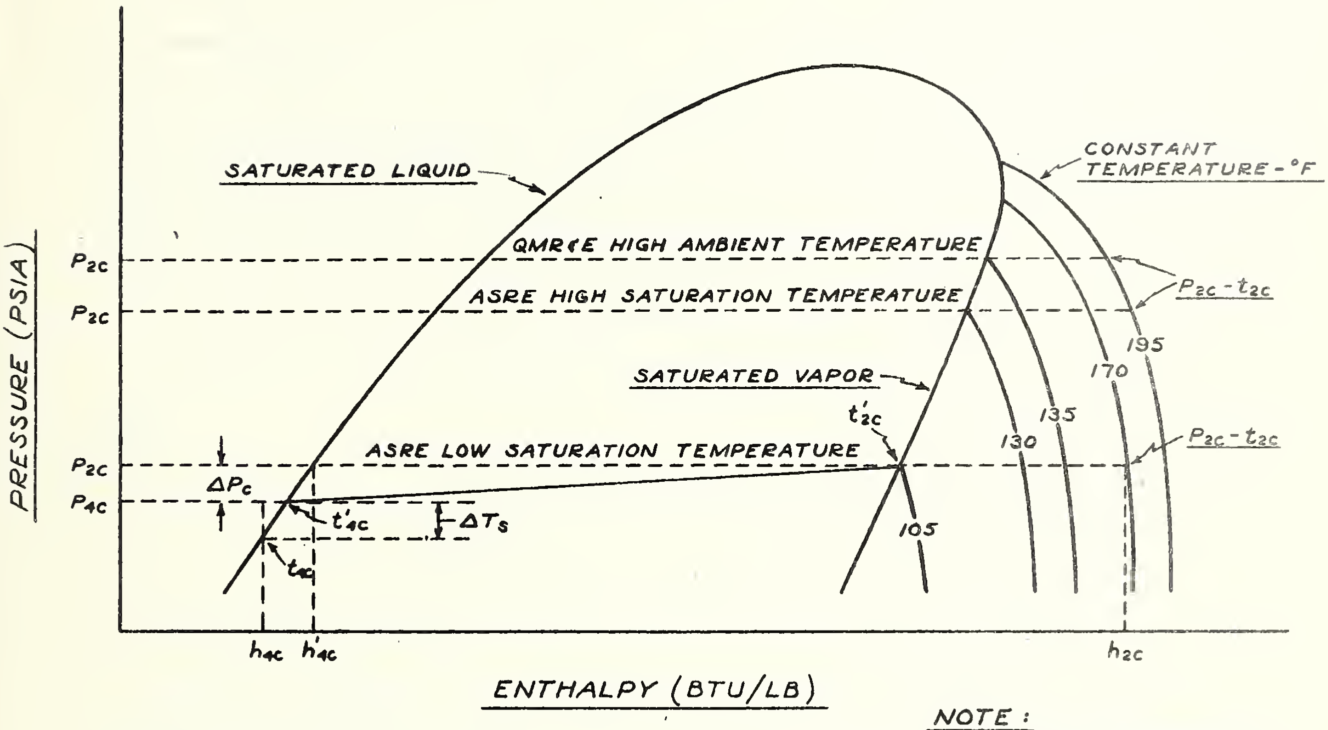


CONDENSER OUTLET MIXER ASSEMBLY

Fig. 13

PRESSURE - ENTHALPY DIAGRAM

NO SCALE



NOTE:
LABELED IN ACCORDANCE WITH ASRE PS 2.4

CONDENSER SPECIMEN DIAGRAM

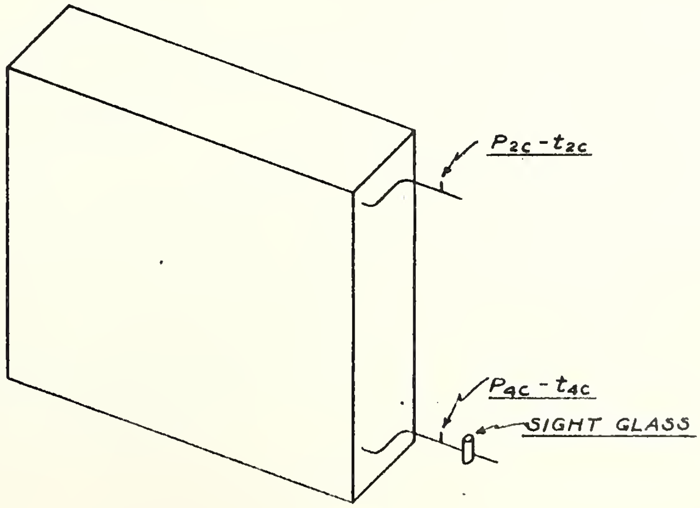


Fig. 14

Photographs and schematic drawings of the four condensers tested are presented in Figures 15 to 23. Dimensional and material data and test results are summarized in Tables 1 to 8.

In each table of test results, Items 1 through 6 are specified test conditions and the corresponding observed conditions; Items 7 and 8, are performance observations based on air-side measurements; Items 9 through 12 are performance observations based on refrigerant-side measurements; and Items 13 through 23 are ratings derived from both sets of measurements. Two additional ratings, Items 24 and 25, have been added for further comparison. They are:

Item 24. Btu per $(ft^2)(°F)(hour)$

Item 25. Btu per $(ft^2)(°F)(CFM)(hour)$

where:

Ft^2 = total surface area of the condenser in square feet

°F = log mean temperature difference, refrigerant to air

CFM = air flow rate, std.

Items 1 through 12, 17, and 18 are observed test results, corrected for gauge calibration, etc. Items 13 through 16 and 19 through 25 are values which have been converted from observed test conditions to standard conditions. Item 13 is the converted average of Items 8 and 12. Item 14, "Condensing Heat Rejection", includes desuperheating of the entering refrigerant vapor. Item 14 was determined using the following equation:

$$q_{cR} = F(h_{2c} - h'_{4c})$$

where q_{cR} = condensing heat rejection, Btu per hour

F = factor, $\left(\frac{q_{tR}}{q_{tr}}\right)$

h_{2c} = enthalpy at P_{2c}, t_{2c}, Btu per pound

h'_{4c} = enthalpy of saturation at P_{2c}, Btu per pound

q_{tR} = total heat rejection, Item 13, Btu per hour

q_{tr} = total heat rejection, Item 12, Btu per hour

It will be noted that this method arbitrarily assumes that all condensing occurs at the inlet pressure.

For all tests reported, the agreement between capacities determined by the air-side or psychrometric method and the flowmeter method was closer than 7 percent, and for all tests except two, the agreement was closer than 4 percent. Agreement for all QMR&E High Ambient Temperature tests was 3.5 percent or less.

Specimen No. 1 was a Size A, Class 1 Condenser, NBS No. 134-57. Figure 15 is a view of this condenser which had copper tubes and aluminum fins. Note the straight line vertical parallel tube rows typical of all condensers in this report as further indicated in Figure 11. Each plate-type fin in this condenser was the full height of the condenser. Figure 16 and Table 1 give dimensional data, and Table 2 presents test data for Specimen No. 1. For this specimen, confirming refrigerant flow rate determinations were made using the secondary refrigerant calorimeter shown in Figure 9. These measurements are given in Item 9 in Table 2, to the left of each of the flowmeter measurements listed in the three main columns of data. Specimen No. 1 was the only condenser in this report tested with the secondary refrigerant calorimeter. Difference between the two flow rate measurements was 3.7, 5.8, and 3.6 percent for the three tests in Table 2. At the QMR&E High Ambient Temperature test, the capacity was 21440 Btu per hour, 96.2% of the requirement of 22300 Btu per hour.

Specimen No. 2 was a Size B, Class 3 Condenser, NBS No. 145-58, with aluminum tubes and fins. The finned portion was formed in two sections, the top section 22 in. high, the bottom section 11 7/8 in. high. There were 215 fins in the top section, 219 in the bottom. Figure 17 is a view of Specimen No. 2. Figure 18 and Table 3 give dimensional data and Tables 4 and 4a present test data for this condenser. Refrigerant test connections to the aluminum manifolds were made using a commercial epoxy resin after difficulty was experienced in attempts to use aluminum solder. Comparative tests were made at the QMR&E High Ambient Temperature condition with and without the mixer (Figures 12 and 13) in the condenser outlet line. Table 4 lists the performance with the mixer and Table 4a gives the test results without the mixer. The total heat rejection, respectively, for the two QMR&E High Ambient Temperature conditions was 34340 and 34640 Btu per hour, an agreement within 0.9%. Confirming refrigerant flow rate determinations were made using the modified dry system primary calorimeter. The agreement between the two flow rates was 0.6, 16.7, 0.1, and 0.6 percent for the four tests in Tables 4 and 4a. The calorimeter flow rates are shown in Item 9 to the left of each main column of test data. As discussed under "Apparatus and Tests", the agreement was satisfactory for all tests except the ASRE Low Saturation Temperature Test, in which the flowmeter indicated

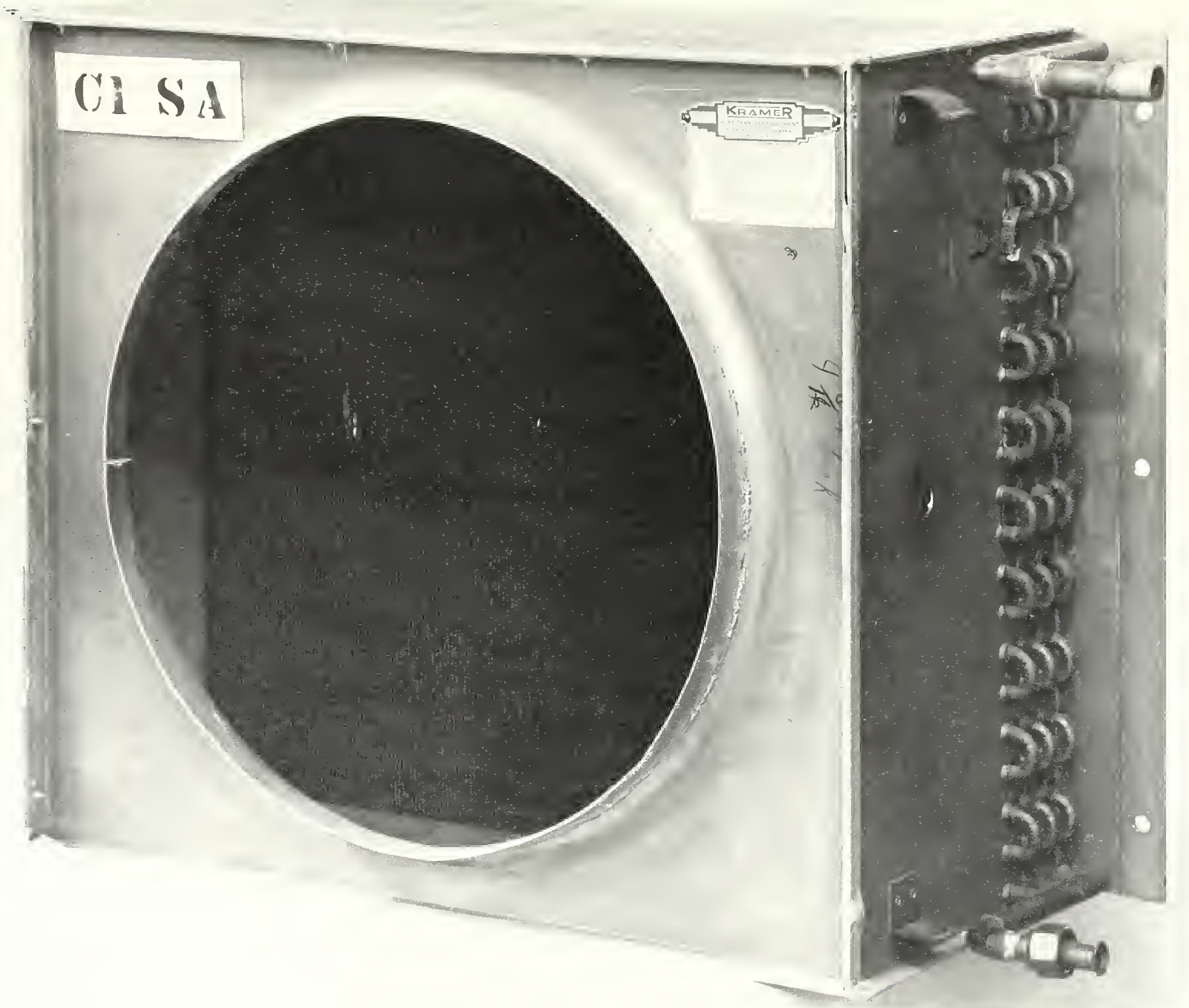


Fig. 15

CONDENSER SPECIMEN No. 1

MFR. KRAMER TRENTON | NBS NO. 134-57 | SIZE A | CLASS 1

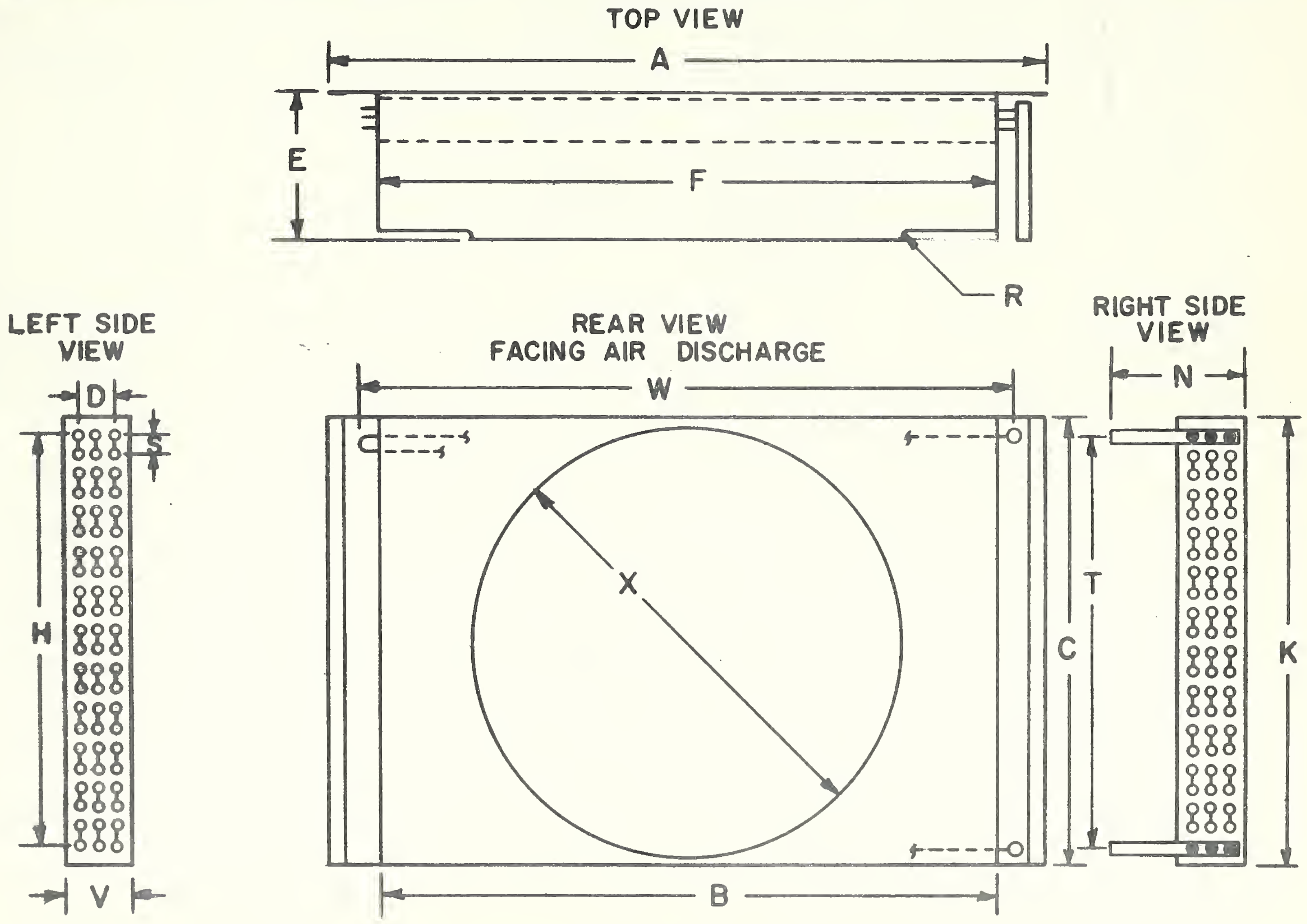


Fig. 16

CONDENSER SPECIMEN No. 1

MFR. KRAMER TRENTON		SIZE - A
NBS NO. 134-57		CLASS - 1
ITEM	PROPERTY	REMARKS
COIL TUBE CHARACTERISTICS		
1 MATERIAL	Copper	
2 NUMBER OF ROWS DEEP	3	
3 NUMBER OF TUBES HIGH	22	
4 NUMBER OF CIRCUITS IN PARALLEL	3	
5 NUMBER OF TUBES PER CIRCUIT	22	
6 TUBE DIAMETER, O.D., IN.	3/8	nominal, see text
7 TUBE WALL THICKNESS, IN.	0.025	approx.
8 TUBE RETURN BEND DIAMETER, O.D., IN.	3/8	nominal, see text
9 GAS INLET CONNECTION DIAM., O.D., IN.	5/8	increased to 7/8"
10 LIQUID OUTLET CONN. DIAMETER, O.D, IN.	5/8	
11 VERTICAL TUBE SPACING, IN. S	1	
12 PRIMARY SURFACE AREA, SQ. FT.	12.4	
COIL FIN CHARACTERISTICS		
1 MATERIAL	Aluminum	
2 TYPE OF FIN	Plate	Embossed, slotted
3 FIN SPACING, PER INCH	8	
4 FIN THICKNESS, IN.	.011	
5 SECONDARY SURFACE AREA, SQ. FT.	145.4	
COIL DIMENSIONS		
1 FINNED HEIGHT, IN. K	21 7/8	
2 FINNED WIDTH, IN. F	24 3/4	190 Fins
3 FINNED DEPTH, IN. V	3	
4 COIL HEIGHT, IN. H	21	
5 COIL WIDTH, IN. W	27 1/4	
6 COIL DEPTH, IN. D	2	
7 COIL DEPTH, OVERALL, IN. N	10 5/8	
8 FACE AREA, SQ. FT.	3.8	
9 TOTAL SURFACE AREA, SQ. FT.	157.8	
OVERALL CONDENSER DIMENSIONS		
1 WIDTH, OVERALL, IN. A	30 1/8	
2 WIDTH, SHROUD, IN. B	24 7/8	
3 HEIGHT, IN. C	22 1/8	
4 DEPTH, IN. E	11	
5 BELLMOUTH ORIFICE DIAMETER, IN. X	18 3/8	
6 BELLMOUTH RADIUS, IN. R	3/4	

Table 1

CONDENSER SPECIMEN No. 1

MFR. KRAMER TRENTON			NBS NO. 134-57			SIZE - A		CLASS - 1	
AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED			ASRE HIGH SATURATION TEMPERATURE			ASRE LOW SATURATION TEMPERATURE		QMR&E HIGH AMBIENT TEMPERATURE	
FAN MFR. — Torrington FAN SERIAL NO. — E-1826-3 FAN SPEED — 1140 MOTOR HP RATING — 1/3 REFRIGERANT — 12			STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM		STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM	STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM
ITEM					FREE DISCH.		FREE DISCHARGE		FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921		29.31	29.921	29.80	29.921	29.75
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95		95.2	95	95.0	110	109.9
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5		79.5	75±5	78.4		90.6
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95		95.2	95	95.0	110	109.9
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130		129.7	105	105.2	135	134.9
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10		194.2	170±10	168.3		195.5
			AIR FLOW METHOD			AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM			2060		2010		2040
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH			29520		7330		21090
			REFRIGERANT FLOW METHOD			REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min		8.130	7.841	1.907	1.803	5.963	5.758
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI			4.0		0.8		2.4
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.		5.7	5° MAX.	4.0		4.6
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH			30630		7310		21780
			RATINGS			RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH			31430		7180		21440
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH			30540		7060		20990
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH			890		120		450
16. AIR FLOW RATE	Q_R	CFM			1820		1840		1780
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O			0.15		0.15		0.15
18. FAN MOTOR POWER	P_{fm}	WATTS			176		130		174
19. FAN BRAKE HORSEPOWER	P	BHP			---		---		---
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA	BTUH/SF				2535		578.9		1729
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA	BTUH/SF				216.2		49.37		147.4
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA	BTUH/SF				199.2		45.49		135.9
23. HEAT REJECTION PER CFM	BTUH				17.27		3.893		12.06
24. " " , BTUH/SF(°F)					7.413		5.294		6.942
25. " " , BTUH/SF(°F)(CFM)					0.00407		0.00287		0.00391

Table 2

Fig. 17

CONDENSER SPECIMEN No. 2

MFR. KRAMER TRENTON | NBS NO. 145-58 | SIZE - B | CLASS - 3

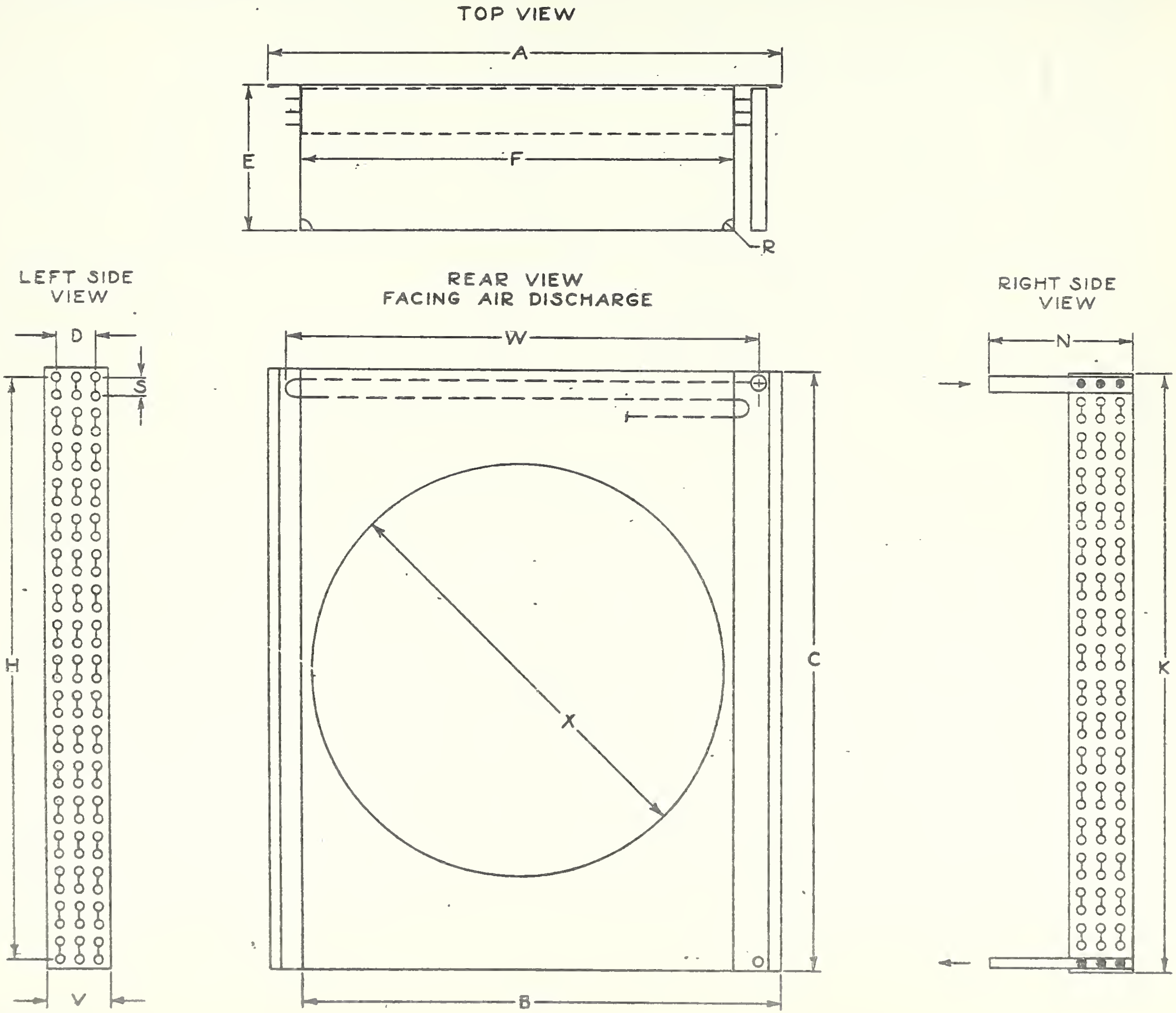


Fig. 18

CONDENSER SPECIMEN No. 2

MFR. KRAMER TRENTON	SIZE - B	
NBS NO. 145-58	CLASS - 3	

ITEM		PROPERTY	REMARKS
COIL TUBE CHARACTERISTICS			
1 MATERIAL		Aluminum	
2 NUMBER OF ROWS DEEP		3	
3 NUMBER OF TUBES HIGH		34	
4 NUMBER OF CIRCUITS IN PARALLEL		3	
5 NUMBER OF TUBES PER CIRCUIT		34	
6 TUBE DIAMETER, O.D., IN.		3/8	nominal, see text
7 TUBE WALL THICKNESS, IN.		0.025	approx.
8 TUBE RETURN BEND DIAMETER, O.D., IN.		3/8	nominal, see text
9 GAS INLET CONNECTION DIAM., O.D., IN.		7/8	
10 LIQUID OUTLET CONN. DIAMETER, O.D., IN.		5/8	
11 VERTICAL TUBE SPACING, IN.	S	1	
12 PRIMARY SURFACE AREA, SQ. FT.		20.8	
COIL FIN CHARACTERISTICS			
1 MATERIAL		Aluminum	
2 TYPE OF FIN		Plate	Embossed, slotted
3 FIN SPACING, PER INCH		8	
4 FIN THICKNESS, IN.		0.011	
5 SECONDARY SURFACE AREA, SQ. FT.		254.9	
COIL DIMENSIONS			
1 FINNED HEIGHT, IN.	K	33 7/8	
2 FINNED WIDTH, IN.	F	27	215 Fins (top section)
3 FINNED DEPTH, IN.	V	3	219 Fins (bottom section)
4 COIL HEIGHT, IN.	H	32 3/4	
5 COIL WIDTH, IN.	W	29 3/8	
6 COIL DEPTH, IN.	D	2	
7 COIL DEPTH, OVERALL, IN.	N	10 5/8	
8 FACE AREA, SQ. FT.		6.4	
9 TOTAL SURFACE AREA, SQ. FT.		275.7	
OVERALL CONDENSER DIMENSIONS			
1 WIDTH, OVERALL, IN.	A	32 3/8	
2 WIDTH, SHROUD, IN.	B	27 1/2	
3 HEIGHT, IN.	C	34	
4 DEPTH, IN.	E	11	
5 BELLMOUTH ORIFICE DIAMETER, IN.	X	24 1/2	
6 BELLMOUTH RADIUS, IN.	R	5/8	Approx.

Table 3

CONDENSER SPECIMEN No. 2

MFR. KRAMER TRENTON NBS NO. 145-58 SIZE - B CLASS - 3

AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED

FAN MFR. —— Torrington
FAN SERIAL NO. —— E-2420-4
FAN SPEED —— 1140
MOTOR HP RATING —— 0.5
REFRIGERANT —— 12

ITEM			ASRE HIGH SATURATION TEMPERATURE: STANDARD CONDITION	ASRE HIGH SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM	ASRE HIGH SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCH.	ASRE LOW SATURATION TEMPERATURE: STANDARD CONDITION	ASRE LOW SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE	QMR & E HIGH AMBIENT TEMPERATURE: STANDARD CONDITION	QMR & E HIGH AMBIENT TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921		29.95	29.921	29.82	29.921	29.73
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95		95.2	95	94.9	110	109.8
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5		78.6	75±5	76.8		87.8
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95		95.2	95	94.9	110	109.8
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130		130.4	105	104.9	135	135.3
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10		191.7	170±10	166.2		197.6
			AIR FLOW METHOD			AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM			3850		3860		3850
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH			47400		12960		34610
			REFRIGERANT FLOW METHOD			REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min		12.43	12.36	2.748	3.297	9.235	9.248
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI			20.3		3.3		11.1
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.		2.0	5° MAX.	4.6		2.9
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH			48260		13510		35440
			RATINGS			RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH			47570		13230		34340
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH			45760		12930		33320
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH			1810		300		1020
16. AIR FLOW RATE	Q_R	CFM			3340		3560		3360
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O			0.22		0.22		0.23
18. FAN MOTOR POWER	P_{fm}	WATTS			478		486		477
19. FAN BRAKE HORSEPOWER	P	BHP			---		---		---
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA		BTUH/SF			2287		636.3		1651
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA		BTUH/SF			186.6		51.92		134.7
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA		BTUH/SF			172.5		48.00		124.6
23. HEAT REJECTION PER CFM		BTUH			14.23		3.723		10.21
24. " " , BTUH/SF(°F)					6.073		6.102		6.082
25. " " , BTUH/SF(°F)(CFM)					0.00182		0.00172		0.00181

Table 4

CONDENSER SPECIMEN No. 2

MFR. KRAMER TRENTON			NBS NO. 145-58				SIZE - B		CLASS - 3	
AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED			ASRE HIGH SATURATION TEMPERATURE				ASRE LOW SATURATION TEMPERATURE		QMR & E HIGH AMBIENT TEMPERATURE	
FAN MFR. — Torrington FAN SERIAL NO. — E-2420-4 FAN SPEED — 1140 MOTOR HP RATING — 0.5 REFRIGERANT — 12			STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM			STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM	STANDARD CONDITION	OBSERVED CONDITION AIR FLOW RATE CFM
ITEM					FREE DISCH.			FREE DISCHARGE		FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"H_g	29.921				29.921		29.921	29.57
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95				95		110	110.0
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5				75±5			87.4
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95				95		110	110.0
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130				105		135	135.2
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10				170±10			199.0
			AIR FLOW METHOD				AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM								3850
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH								34290
			REFRIGERANT FLOW METHOD				REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min							9.267	9.215
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI								9.6
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.				5° MAX.			4.0
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH								35530
			RATINGS				RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH								34640
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH								33570
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH								1070
16. AIR FLOW RATE	Q_R	CFM								3360
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O								0.22
18. FAN MOTOR POWER	P_{fm}	WATTS								477
19. FAN BRAKE HORSEPOWER	P	BHP								---
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA	BTUH/SF									1665
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA	BTUH/SF									135.9
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA	BTUH/SF									125.6
23. HEAT REJECTION PER CFM	BTUH									10.32
24. " " , BTUH/SF(°F)										6.200
25. " " , BTUH/SF(°F)(CFM)										0.00185

Table 4a

a flow rate of less than 4 pounds per minute. At the QMR&E High Ambient Temperature Test with the mixer, the capacity was 34340 Btu per hour, 96.4% of the requirement of 35600 Btu per hour.

Specimen No. 3 was a size B, Class 2 Condenser, NBS No. 146-58, with copper tubes and copper fins. The fin and tube assembly was as shown in Figure 11, and Figure 19 is a view of this specimen. The finned portion of the condenser was formed in two sections. The top section was 22 in. high, with 211 fins, and the bottom section was 12 in. high, with 212 fins. Figure 20 and Table 5 contain dimensional data, and Table 6 contains test data for Specimen No. 3. Refrigerant flow rate determination, in addition to the flowmeter measurement, was made using the dry system primary calorimeter for the first two tests shown in Table 6. The calorimeter flow rates are listed in Item 9 to the left of each of the first two main columns of test data. Agreement between the two measurements was 1.1 and 13.4 percent, with the poor agreement occuring at a flow rate of less than four pounds per minute. The third test reported in Table 6 was made prior to modification of the system evaporator to serve as a calorimeter. The capacity at the QMR&E High Ambient Temperature Test was 33210 Btu per hour, 93.3 percent of the requirement of 35600 Btu per hour.

Specimen No. 4 was a Size C, Class 1 Condenser, NBS No. 150-58, with copper tubes and aluminum fins. The finned portion was divided into two sections. The top section was 22 in. high, with 301 fins, and the bottom section was 9 7/8 in. high, with 308 fins. Figure 11 shows the typical tube and fin arrangement. Figure 21 is a view of Specimen No. 4 showing the fan orifice and manifold end of the condenser. Figure 22 shows the air inlet face of this condenser in an inverted position. Figure 23 and Table 7 present dimensional data, and Table 8 contains test data for Specimen No. 4. Refrigerant flow rate determinations were made using the dry system primary calorimeter in addition to the flowmeter measurements. The calorimeter rates are listed in Item 9 of Table 8 to the left of the flowmeter rates in each main column of test data. Agreement between the two measurements of refrigerant flow rate was 0, 8.1, and 2.1 percent for the three tests. At the QMR&E High Ambient Temperature Test, the capacity was 47,980 Btu/hr, 104.3 percent of the requirement.

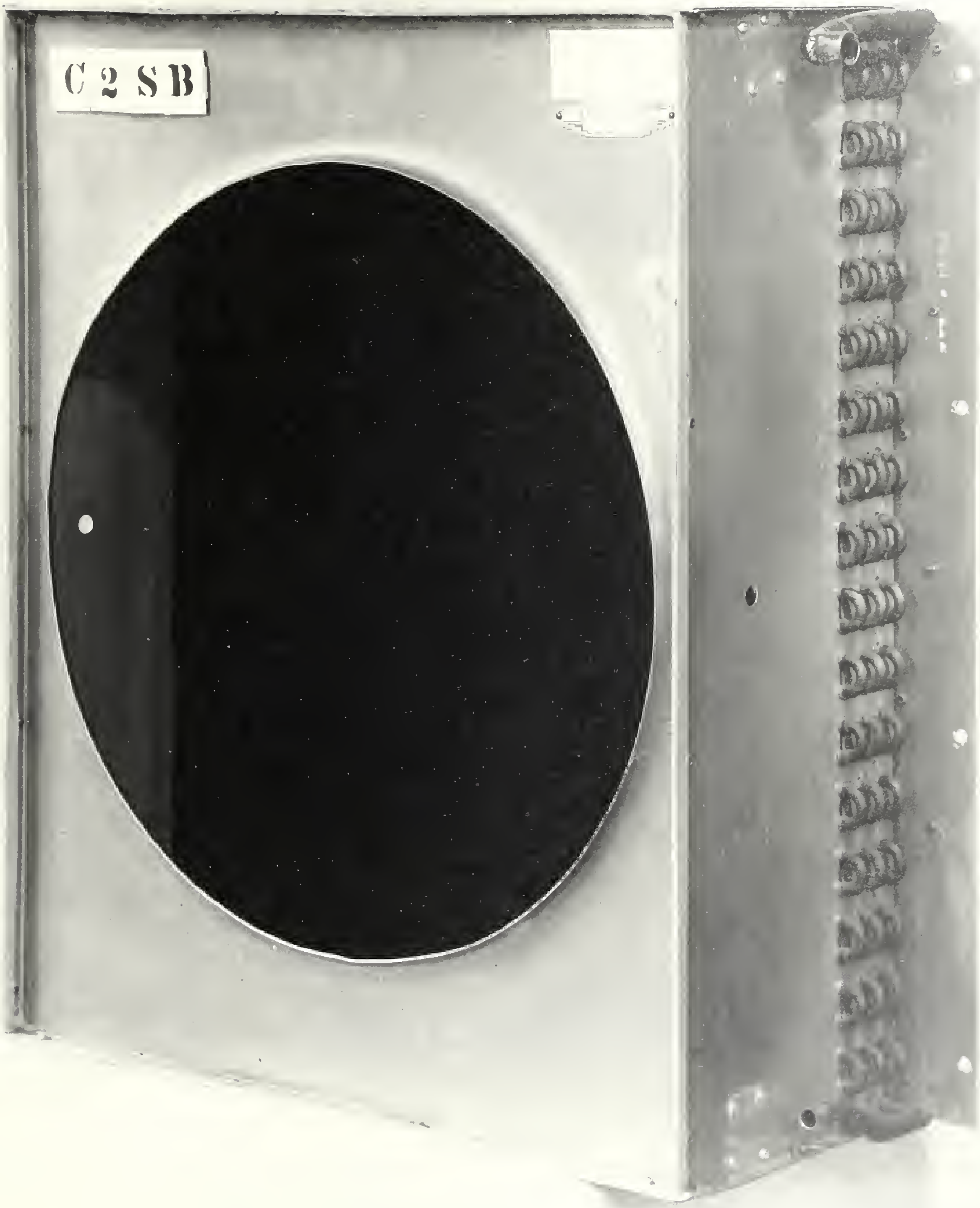


Fig. 19

CONDENSER SPECIMEN No. 3

MFR. KRAMER TRENTON | NBS NO. 146-58 | SIZE B | CLASS 2

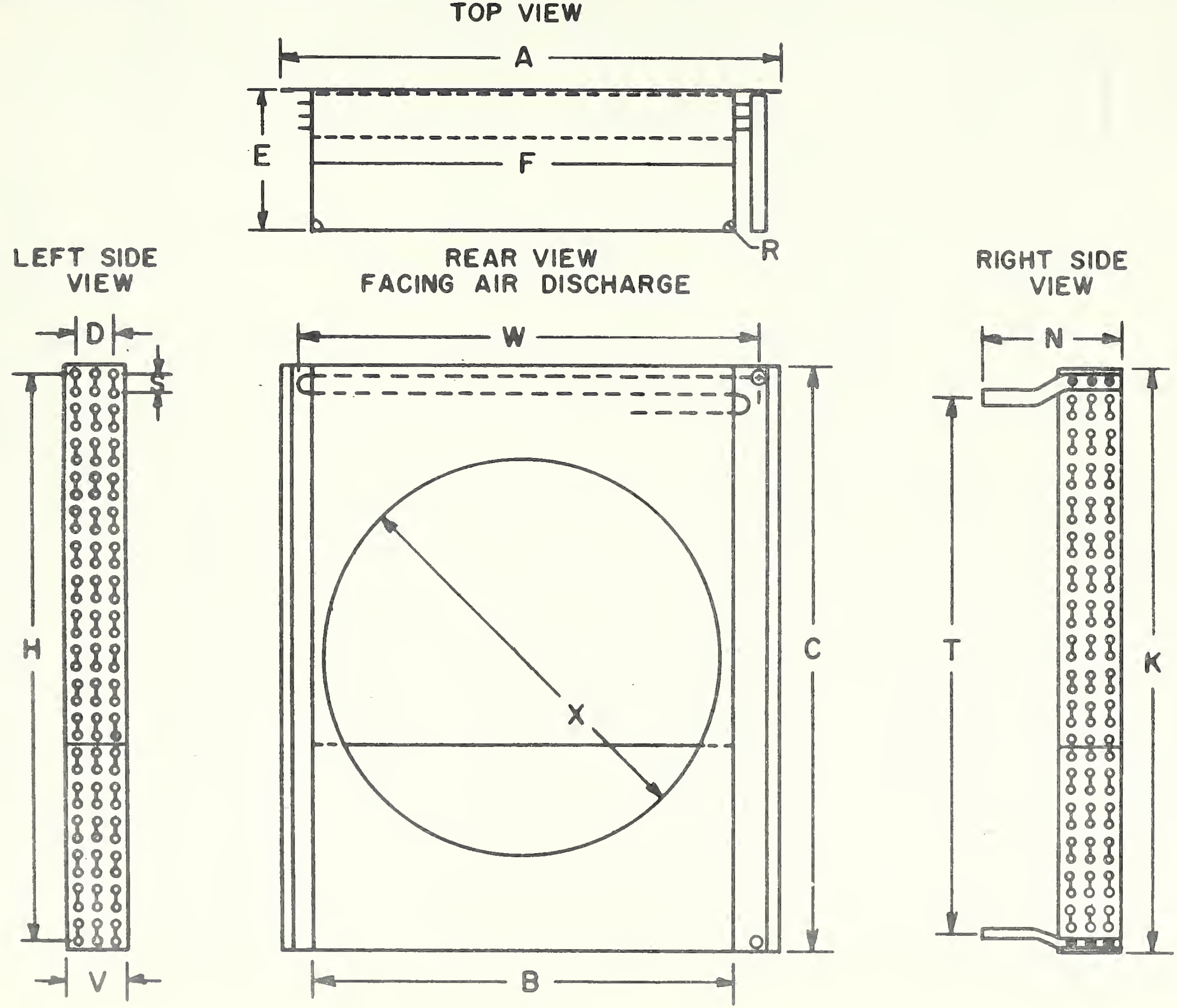


Fig. 20

CONDENSER SPECIMEN No. 3

MFR. KRAMER TRENTON		SIZE - B
NBS NO. 146-58		CLASS - 2
ITEM	PROPERTY	REMARKS
		COIL TUBE CHARACTERISTICS
1 MATERIAL	Copper	
2 NUMBER OF ROWS DEEP	3	
3 NUMBER OF TUBES HIGH	34	
4 NUMBER OF CIRCUITS IN PARALLEL	3	
5 NUMBER OF TUBES PER CIRCUIT	34	
6 TUBE DIAMETER, O.D., IN.	3/8	nominal, see text
7 TUBE WALL THICKNESS, IN.	0.025	approx.
8 TUBE RETURN BEND DIAMETER, O.D., IN.	3/8	nominal, see text
9 GAS INLET CONNECTION DIAM., O.D., IN.	7/8	
10 LIQUID OUTLET CONN. DIAMETER, O.D, IN.	5/8	
11 VERTICAL TUBE SPACING, IN. S	1	
12 PRIMARY SURFACE AREA, SQ. FT.	21.1	
		COIL FIN CHARACTERISTICS
1 MATERIAL	Copper	
2 TYPE OF FIN	Plate	Embossed, slotted
3 FIN SPACING, PER INCH	8	
4 FIN THICKNESS, IN.	.009-.011	
5 SECONDARY SURFACE AREA, SQ. FT.	251.3	
		COIL DIMENSIONS
1 FINNED HEIGHT, IN. K	34	
2 FINNED WIDTH, IN. F	27 1/8	211 Fins (top section)
3 FINNED DEPTH, IN. V	3	212 Fins (bottom section)
4 COIL HEIGHT, IN. H	33	
5 COIL WIDTH, IN. W	29 1/2	
6 COIL DEPTH, IN. D	2	
7 COIL DEPTH, OVERALL, IN. N	10 5/8	
8 FACE AREA, SQ. FT.	6.4	
9 TOTAL SURFACE AREA, SQ. FT.	272.4	
		OVERALL CONDENSER DIMENSIONS
1 WIDTH, OVERALL, IN. A	32 1/2	
2 WIDTH, SHROUD, IN. B	27.4	
3 HEIGHT, IN. C	34.1.	
4 DEPTH, IN. E	11	
5 BELLMOUTH ORIFICE DIAMETER, IN. X	24 5/8	
6 BELLMOUTH RADIUS, IN. R	5/8	

Table 5

CONDENSER SPECIMEN No. 3

MFR. KRAMER TRENTON — NBS NO. 146-58 — SIZE - B — CLASS - 2

AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED

FAN MFR. — Torrington
FAN SERIAL NO. — E-2420-4
FAN SPEED — 1140
MOTOR HP RATING — 0.5
REFRIGERANT — 12

ITEM			ASRE HIGH SATURATION TEMPERATURE: STANDARD CONDITION	OBSERVED CONDITION, AIR FLOW RATE CFM: HIGH	FREE DISCH.	LOW	ASRE LOW SATURATION TEMPERATURE: STANDARD CONDITION	OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE	QMR&E HIGH AMBIENT TEMPERATURE: STANDARD CONDITION	OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921		29.59		29.921	29.81	29.921	29.42
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95		95.1		95	95.2	110	110.0
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5		79.1		75±5	76.9		75.0
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95		95.1		95	95.2	110	110.0
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{2c}	°F	130		130.2		105	105.2	135	135.1
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{2c}	°F	195±10		196.1		170±10	171.8		197.4
			AIR FLOW METHOD				AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM			3860			3820		3580
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH			52800			14910		33240
			REFRIGERANT FLOW METHOD				REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min		13.31	13.17		3.397	3.923		8.623
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI			14.9			2.0		8.25
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.		10.2		5° MAX.	2.6		7.9
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH			53190			16010		33560
			RATINGS				RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH			52940			15460		33210
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH			49720			15260		31740
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH			3220			200		1470
16. AIR FLOW RATE	Q_R	CFM			3450			3510		3190
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O			0.21			0.22		0.16
18. FAN MOTOR POWER	P_{fm}	WATTS			464			497		503
19. FAN BRAKE HORSEPOWER	P	BHP			---			---		---
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA		BTUH/SF			2509			732.6		1575
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA		BTUH/SF			210.7			61.51		132.2
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA		BTUH/SF			194.3			56.74		122.0
23. HEAT REJECTION PER CFM		BTUH			15.34			4.405		10.41
24. " " , BTUH/SF(°F)					7.090			7.358		6.110
25. " " , BTUH/SF(°F)(CFM)					0.00206			0.00210		0.00191

Table 6

Fig. 21

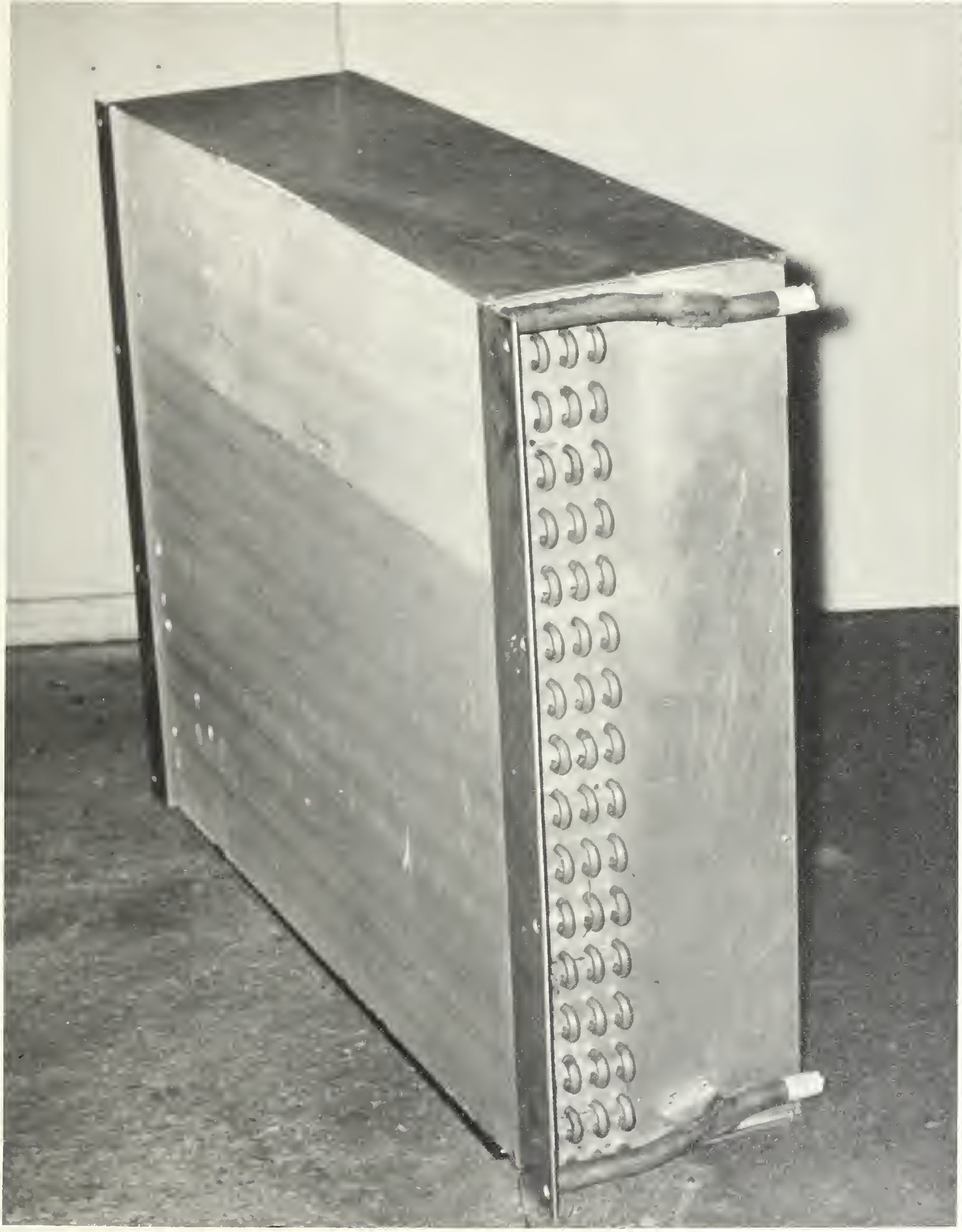


Fig. 22

CONDENSER SPECIMEN No. 4

MFR. KRAMER TRENTON NBS NO. 150-58 SIZE C CLASS 1

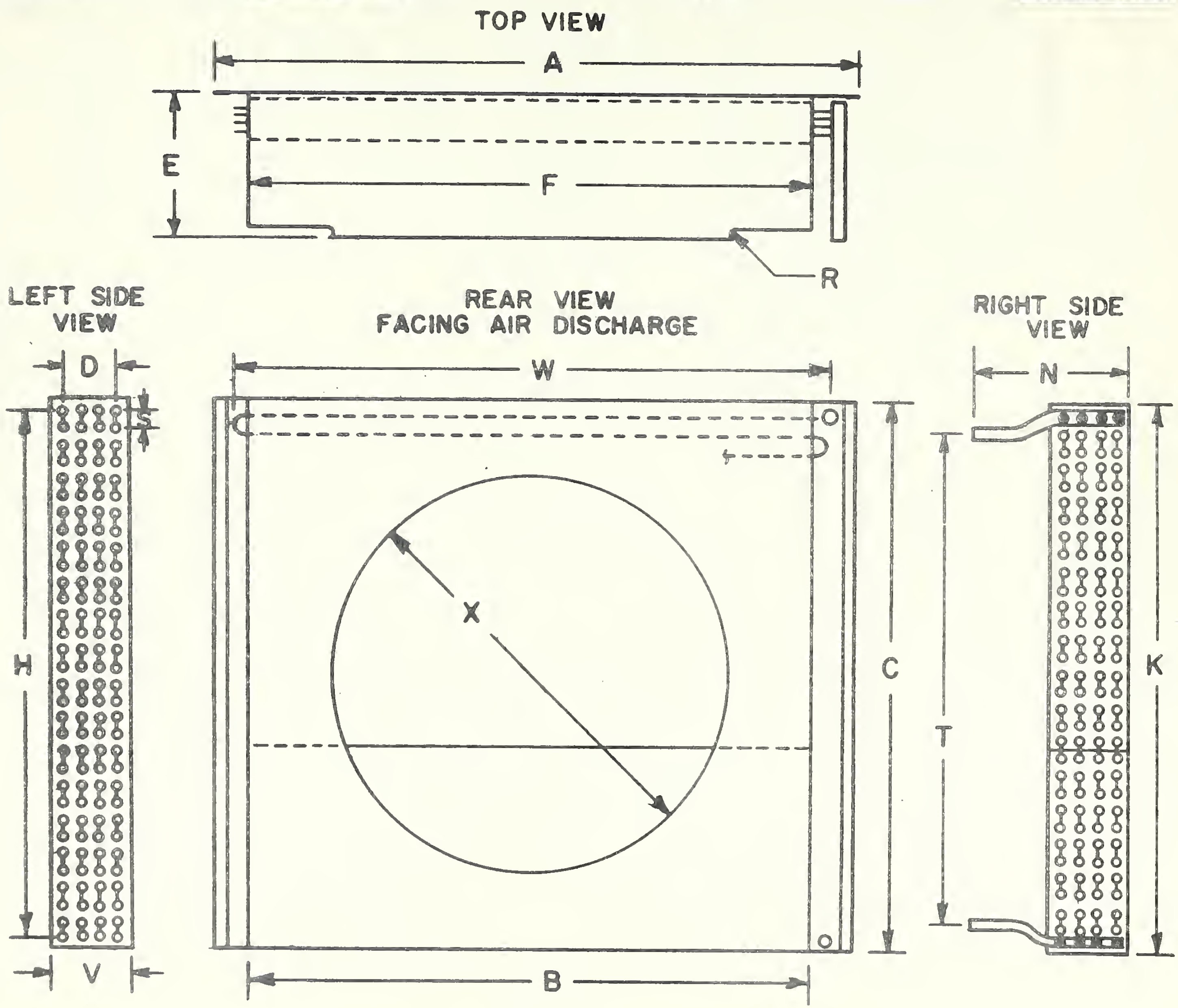


Fig. 23

CONDENSER SPECIMEN No. 4

MFR. KRAMER TRENTON		SIZE - C
NBS NO. 150-58		CLASS - 1
ITEM	PROPERTY	REMARKS
	COIL TUBE CHARACTERISTICS	
1 MATERIAL	Copper	
2 NUMBER OF ROWS DEEP	4	
3 NUMBER OF TUBES HIGH	32	
4 NUMBER OF CIRCUITS IN PARALLEL	4	
5 NUMBER OF TUBES PER CIRCUIT	32	
6 TUBE DIAMETER, O.D., IN.	3/8	nominal, see text
7 TUBE WALL THICKNESS, IN.	0.025	approx.
8 TUBE RETURN BEND DIAMETER, O.D., IN.	3/8	nominal, see text
9 GAS INLET CONNECTION DIAM., O.D., IN.	7/8	
10 LIQUID OUTLET CONN. DIAMETER, O.D, IN.	7/8	
11 VERTICAL TUBE SPACING, IN. S	1	
12 PRIMARY SURFACE AREA, SQ. FT.	36.9	
	COIL FIN CHARACTERISTICS	
1 MATERIAL	Aluminum	
2 TYPE OF FIN	Plate	Embossed, slotted
3 FIN SPACING, PER INCH	8	
4 FIN THICKNESS, IN.	0.011	
5 SECONDARY SURFACE AREA, SQ. FT.	447.8	
	COIL DIMENSIONS	
1 FINNED HEIGHT, IN. K	31 7/8	
2 FINNED WIDTH, IN. F	38 1/8	301 Fins (top section)
3 FINNED DEPTH, IN. V	4	308 Fins (bottom section)
4 COIL HEIGHT, IN. H	31	
5 COIL WIDTH, IN. W	39 7/8	
6 COIL DEPTH, IN. D	3	
7 COIL DEPTH, OVERALL, IN. N	10 5/8	
8 FACE AREA, SQ. FT.	8.4	
9 TOTAL SURFACE AREA, SQ. FT.	484.7	
	OVERALL CONDENSER DIMENSIONS	
1 WIDTH, OVERALL, IN. A	43 1/2	
2 WIDTH, SHROUD, IN. B	38 1/4	
3 HEIGHT, IN. C	31 7/8	
4 DEPTH, IN. E	11 1/8	
5 BELLMOUTH ORIFICE DIAMETER, IN. X	24 5/8	
6 BELLMOUTH RADIUS, IN. R	3/4	

Table 7

CONDENSER SPECIMEN No. 4

MFR. KRAMER TRENTON — NBS NO. 150-58 — SIZE - C — CLASS - 1

AIR CIRCULATING EQUIPMENT AND REFRIGERANT USED

- FAN MFR. — Torrington
- FAN SERIAL NO. — E-2420-4
- FAN SPEED — 1140
- MOTOR HP RATING — 0.5
- REFRIGERANT — 12

ITEM			ASRE HIGH SATURATION TEMPERATURE: STANDARD CONDITION	ASRE HIGH SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM	ASRE HIGH SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCH.	ASRE LOW SATURATION TEMPERATURE: STANDARD CONDITION	ASRE LOW SATURATION TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE	QMR&E HIGH AMBIENT TEMPERATURE: STANDARD CONDITION	QMR&E HIGH AMBIENT TEMPERATURE: OBSERVED CONDITION, AIR FLOW RATE CFM: FREE DISCHARGE
1. BAROMETRIC PRESSURE	P_{ab}	"Hg	29.921		29.88	29.921	29.86	29.921	29.80
2. DRY BULB TEMPERATURE OF AIR ENTERING COIL	t_{ae}	°F	95		95.0	95	94.8	110	109.9
3. WET BULB TEMPERATURE OF AIR ENTERING COIL	t'_{ae}	°F	75±5		78.0	75±5	77.3		86.2
4. DRY BULB TEMPERATURE OF AMBIENT AIR	t_{ae}	°F	95		95.0	95	94.8	110	109.9
5. SATURATION TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t'_{zc}	°F	130		130.0	105	104.8	135	135.0
6. SUPERHEAT TEMPERATURE OF ENTERING REFRIGERANT VAPOR	t_{zc}	°F	195±10		195.1	170±10	173.8		192.2
			AIR FLOW METHOD			AIR FLOW METHOD			
7. NOZZLE AIR AND WATER VAPOR MIXTURE FLOW RATE	Q_{ad}	CFM			3780		3760		3770
8. TOTAL HEAT REJECTION CAPACITY	q_{tc}	BTUH			66350		18600		48490
			REFRIGERANT FLOW METHOD			REFRIGERANT FLOW METHOD			
9. REFRIGERANT FLOW RATE	W_r	lb/min		16.58	16.58	4.317	4.696	12.91	12.65
10. CONDENSER COIL INTERNAL PRESSURE DROP	ΔP_c	PSI			17.9		1.5		9.4
11. SUBCOOLING OF LEAVING REFRIGERANT LIQUID	ΔT_s	°F	10° MAX.		3.2	5° MAX.	3.4		3.9
12. TOTAL HEAT REJECTION CAPACITY	q_{tr}	BTUH			65720		19340		47860
			RATINGS			RATINGS			
13. TOTAL HEAT REJECTION	q_{tR}	BTUH			66030		18970		47980
14. CONDENSING HEAT REJECTION	q_{cR}	BTUH			63320		18690		46500
15. SUBCOOLING HEAT REJECTION	q_{sR}	BTUH			2710		280		1480
16. AIR FLOW RATE	Q_R	CFM			3400		3460		3290
17. CONDENSER COIL EXTERNAL RESISTANCE	P_{as}	"H_2O			0.10		0.11		0.10
18. FAN MOTOR POWER	P_{fm}	WATTS			473		481		469
19. FAN BRAKE HORSEPOWER	P	BHP			---		---		---
20. HEAT REJECTION PER UNIT PRIMARY SURFACE AREA	BTUH/SF				1790		514.2		1300
21. HEAT REJECTION PER UNIT SECONDARY SURFACE AREA	BTUH/SF				147.5		42.37		107.2
22. HEAT REJECTION PER UNIT TOTAL SURFACE AREA	BTUH/SF				136.2		39.14		99.00
23. HEAT REJECTION PER CFM	BTUH				19.43		5.488		14.57
24. " " , BTUH/SF(°F)					5.480		5.444		6.051
25. " " , BTUH/SF(°F)(CFM)					0.00161		0.00158		0.00184

Table 8

4.0 Comparison of Five Kramer Trenton Condensers

Table 9 shows the total heat rejection capacity for five Kramer Trenton condensers (including two Size B condensers previously reported in NBS Report No. 6670). Also shown is the percent of QMR&E requirement (22,300, 35,600 and 46,000 BTUH for Sizes A, B and C, respectively) for the QMR&E High Ambient Temperature Test.

Table 9

TOTAL HEAT REJECTION OF FIVE KRAMER TRENTON CONDENSERS

			Total Heat Rejection, BTUH			
Condenser NBS No.	Class	Size	ASRE High Sat'n Temp.	ASRE Low Sat'n Temp.	QMR&E High Amb.	QMR&E Requirement %
134-57	1	A	31430	7180	21440	96.2
147-58	1	B	-	-	32750[a,b]	92.0
146-58	2	B	52940	15460	33210[a,b]	93.3
145-58	3	B	47570	13230	34340 34640[b]	96.4 97.4
150-58	1	C	66030	18970	47980	104.3

[a]Previously reported in NBS Report No. 6670
[b]Without mixer

Table 10 lists the Heat Transmission Coefficient, BTUH per Ft^2 (°F log mean temperature difference), (Item 24 in Tables of Test Results), and the air entering face velocity based on CFM at test conditions (Item 7, Tables of Test Results), for the five Kramer Trenton condensers.

Table 10

HEAT TRANSMISSION COEFFICIENT OF FIVE KRAMER TRENTON CONDENSERS

Condenser NBS No.	Class	Size	ASRE High Saturation Temp.		ASRE Low Saturation Temp.		QMR&E High Ambient	
			Trans. Coeff. BTUH/ft^2(°F)	Air Face Vel. FPM[a]	Trans. Coeff. BTUH/ft^2(°F)	Air Face Vel. FPM[a]	Trans. Coeff. BTUH/ft^2(°F)	Air Face Vel. FPM[a]
134-57	1	A	7.41	540	5.29	530	6.94	535
147-58	1	B	-	-	-	-	5.84[b,c]	560
146-58	2	B	7.09	605	7.36	595	6.11[b,c]	560
145-58	3	B	6.07	600	6.10	600	6.08 6.20[c]	600 600
150-58	1	C	5.48	450	5.44	450	6.05	450

[a]Based on CFM at test conditions (Item 7, Tables of Test Results)
[b]Adjusted from value reported earlier in NBS Report No. 6670
[c]Without mixer

Table 11 gives the Heat Transmission Coefficient, BTUH per Ft^2 (°F log mean temperature difference)(CFM), (Item 25 in Tables of Test Results) for the five Kramer Trenton condensers.

Table 11

HEAT TRANSMISSION COEFFICIENT OF FIVE KRAMER TRENTON CONDENSERS

			Coefficient, BTUH Per Ft^2 (°F log Mtd)(CFM[a])		
Condenser NBS No.	Class	Size	ASRE High Sat'n Temp.	ASRE Low Sat'n Temp.	QMR&E High Amb.
134-57	1	A	0.00407	0.00287	0.00391
147-58	1	B	-	-	0.00182[b,c]
146-58	2	B	0.00206	0.00210	0.00191[b,c]
145-58	3	B	0.00182	0.00172	0.00181 0.00185[c]
150-58	1	C	0.00161	0.00158	0.00184

[a]Based on standard air (Item 16 in Tables of Test Results)
[b]Adjusted from value reported earlier in NBS Report No. 6670
[c]Without mixer

Table 12 gives the Heat Transmission Coefficient, BTUH per Ft^2 (°F log mean temperature difference)(FPM entering air velocity).

Table 12

HEAT TRANSMISSION COEFFICIENT OF FIVE KRAMER TRENTON CONDENSERS

Condenser NBS No.	Class	Size	Coefficient, BTUH Per Ft^2 (°F log Mtd)(FPM[a]) ASRE High Sat'n Temp.	ASRE Low Sat'n Temp.	QMR&E High Amb.
134-57	1	A	0.0137	0.00998	0.0130
147-58	1	B	-	-	0.0104[b]
146-58	2	B	0.0117	0.0124	0.0109[b]
145-58	3	B	0.0101	0.0102	0.0101 0.0103[b]
150-58	1	C	0.0122	0.0121	0.0134

[a]Based on entering air velocity at test conditions
[b]Without mixer

5.0 Discussion and Recommendations

Review of the test results in this report and others which have preceded it in this series indicates need for specification of maximum refrigerant pressure drop to be maintained during rating tests for selection of equivalent-duty condensers. Complete condensing and minimum subcooling consistent with this pressure drop should also be required. These requirements should be added to the other obvious items such as physical size, weight, materials, capacity at specified conditions, etc.

The present practice, as suggested in ASHRAE 20-60, of listing the air moving capacity of the fan in a given condenser in units of standard CFM may be misleading in that the volume of air handled by a given fan in a fixed system is essentially constant for a range of temperatures. If a fan in a given condenser under test at 110°F entering air temperature and 50 percent relative humidity is found to move, say, 4000 CFM, that same fan and condenser operating at standard conditions would still move nearly 4000 CFM but at higher density and horsepower. Listing the performance of the fan in standard CFM for the actual flow measured at the test conditions would show approximately

$$4000 \times \frac{13.33}{15.00} = 3560 \text{ CFM Std.}$$

assuming standard barometric pressure, whereas the fan volume actually would not drop to this level even if it were operated at standard conditions. It would appear preferable to list the actual CFM at the test conditions in both ratings and requirements.

The critical effect of placing the fan in the condenser shroud orifice can be observed by comparing the measured air flow for the three tests in Table 4, 3850, 3860, and 3850 CFM and in Table 8, 3780, 3760, and 3770 CFM with the measured flow rates in the three tests in Table 6, 3860, 3820, and 3580. In Tables 4 and 8, the three tests were made without changing the relative position of the fan and shroud orifice. In Table 6, the first two tests were made at one time, and the third test at another time, with removal and reinstallation of the test condenser occuring between the two times. Even though considerable care was given to mounting the same fan in each instance in similar position, the difference of 260 CFM was probably caused by dissimilar mounting.

Par. 6.3.4 of ASHRAE 20-60 should be corrected to read, "Condensing heat rejection effect: $q_c = W_{rp} (h_{r1} - h_{f1})$, Btuh". Note discussion in "Data and Results" of procedure used to calculate the condensing heat rejection.

The total heat rejection (Item 13 of the Tables of Test Results) shown for all of the condensers tested in this series was determined by averaging the heat rejection determined by both the air-side, and refrigerant flowmeter measurements, and correcting for deviation from specified test conditions. This method of computation was recommended in ASRE PS-2.4, and for sake of continuity was continued for all tests in the series, even though ASHRAE 20-60 recommended a different computation method. ASHRAE 20-60 differs in that the heat rejection calculated from the flow rate measured by the (primary) refrigerant calorimeter is taken as the total heat rejection without correction for deviation from specified test conditions, provided the confirming flow rate determined by the (secondary) flowmeter is within ± 5 percent of the flow rate determined by the calorimeter.

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